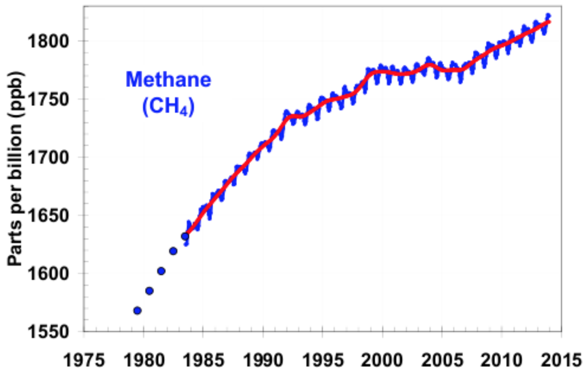
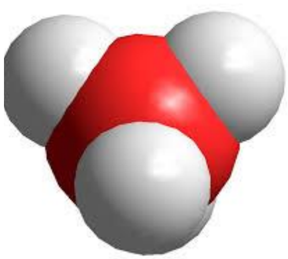
GLOBAL CARBON PROJECT

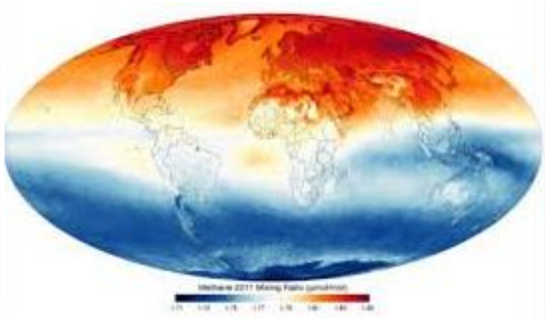
The global methane cycle

P. Bousquet, M. Saunois, A. Peregon, S. Peng, P. Ciais, LSCE, France

Ben Poulter, Montana State University, Ecosystem Dynamics Lab., USA

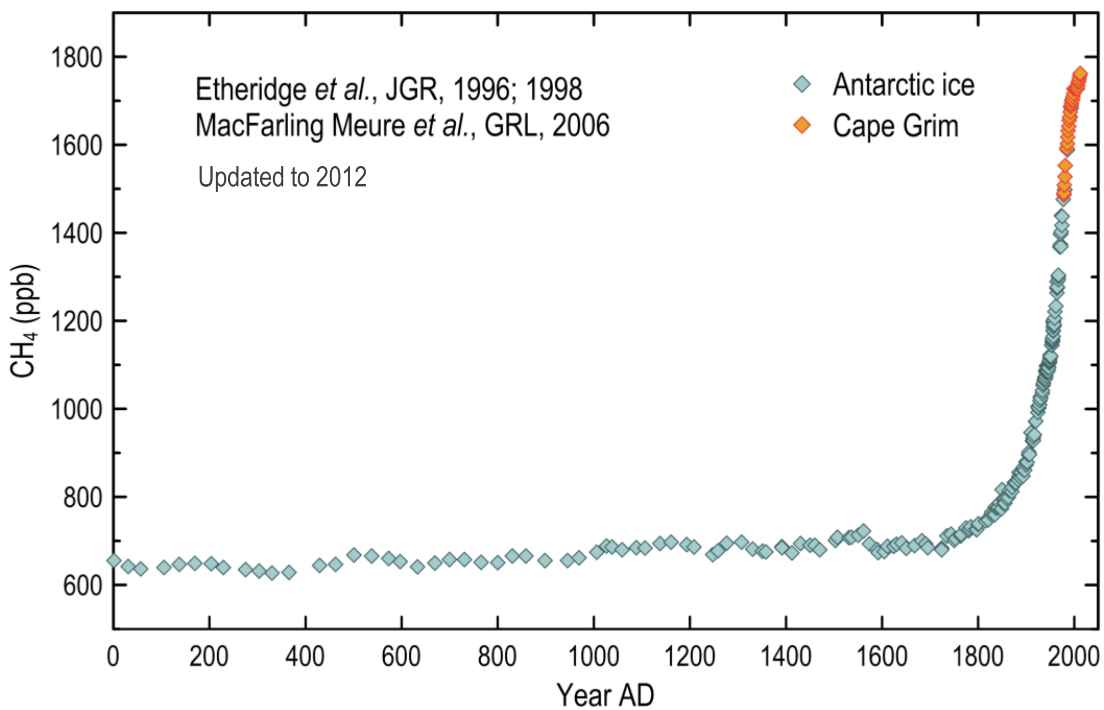


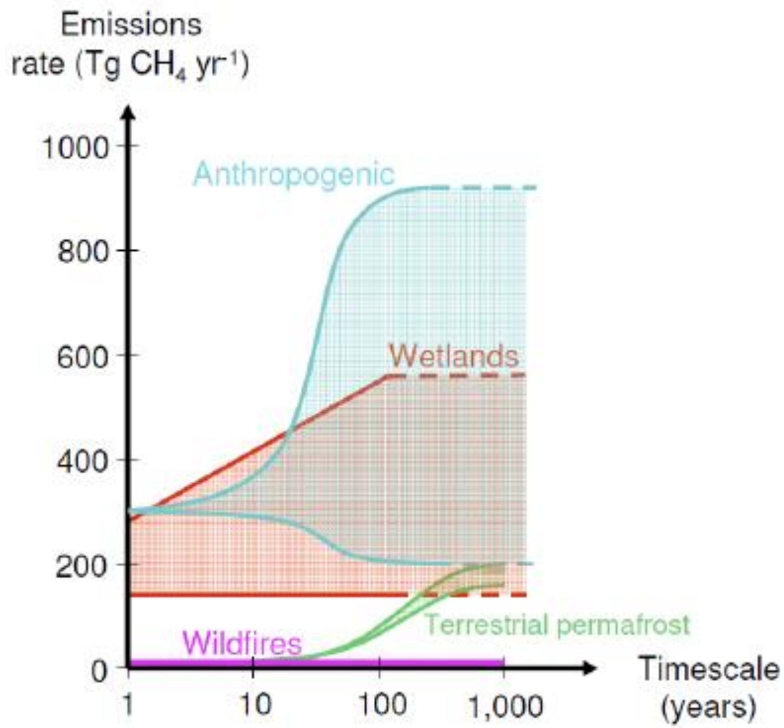




Why methane ?

- Increase by 150%, from 722 ppb to >1820 ppb in 2015
- Responsible for 20% of increase in radiative forcing since 1750 (GWP ~28xCO_2 over 100 yrs)
- Contributes to water vapor production in stratosphere and O_3 production in troposphere
- Lifetime of CH_4 is 8-10 years, then converts to CO_2 (0.8 TgC yr^{-1}, Le Quere et al. 2014)
- Future CH_4 emissions are highly uncertain (i.e., permafrost, gas hydrates, wetlands)





IPCC AR5

Atmospheric Observations	Emission Inventories (B-U)	Biogeochemistry Models (B-U)	Inverse Models (T-D)	Chemical Sink

The Tools and Data

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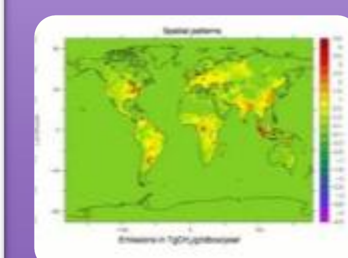

Chemical Sink

Long-term trends and decadal variability of the OH sink.

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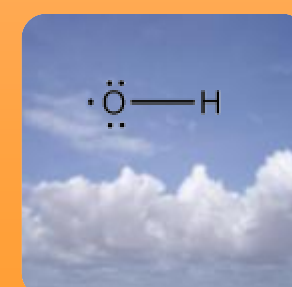
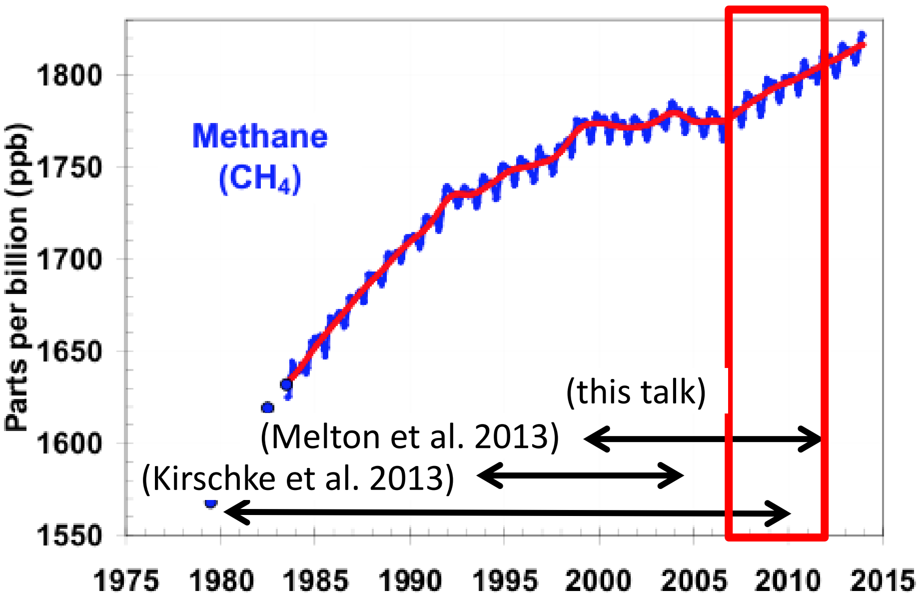
Coming in 2015 : CCMI runs

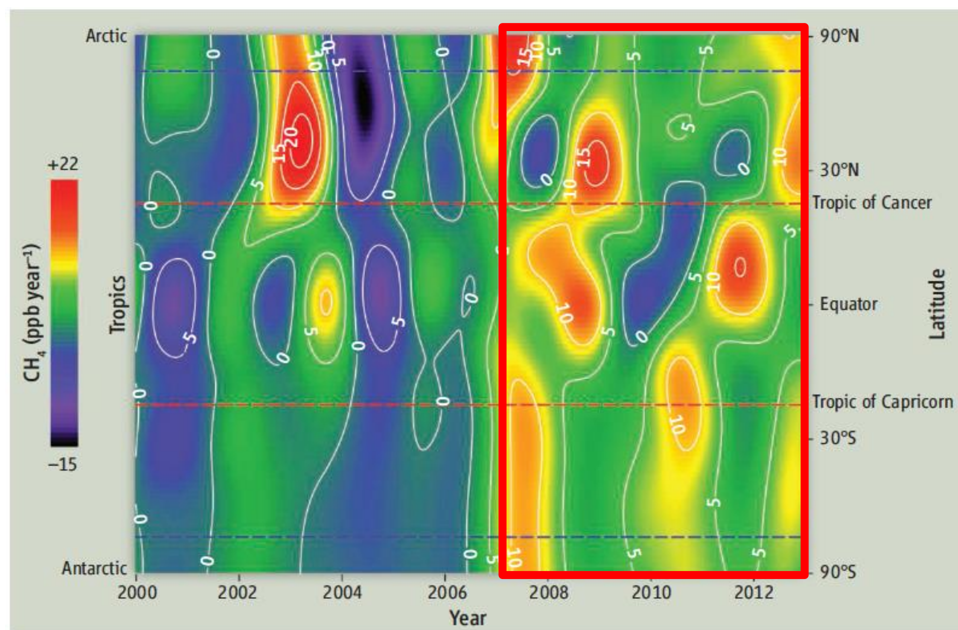


Recent trends in atmospheric CH_4 concentrations

- Following a decade of stable CH_4 concentrations, there has been renewed growth
- CH_4 is increasing at a rate of ~6 ppb yr^{-1} since 2007
- Cause is unknown:
  - 4% decrease in OH (Rigby et al. 2008)
  - Increase/decrease in anthropogenic and/or natural emissions and/or chemical loss
- CH_4 assessments need to be updated

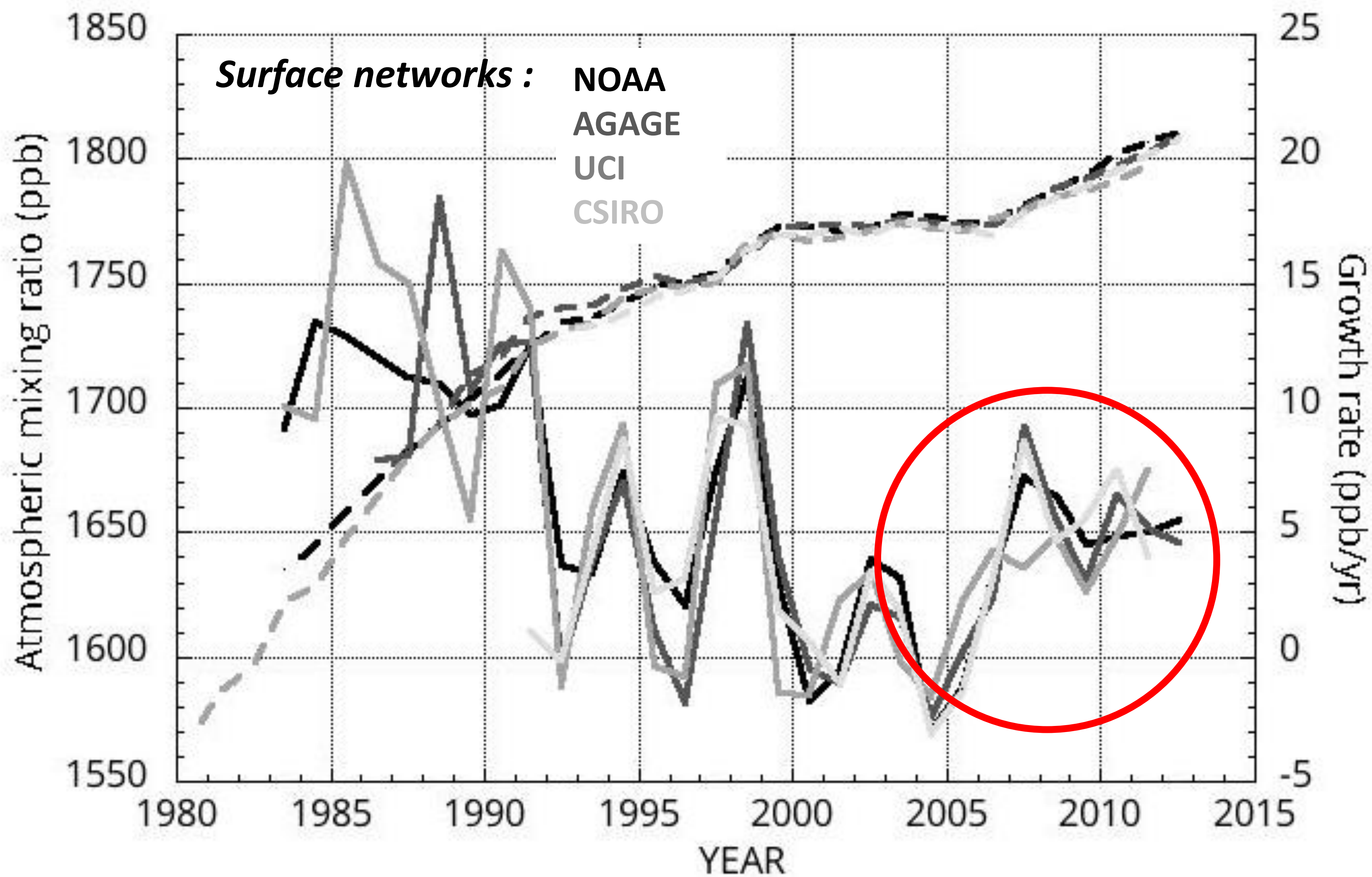


NOAA 2015



Rigby et al. 2008
Nisbet et al. 2013

Global mixing ratio & growth rate : 1980-2012



A challenging signal to analyse !

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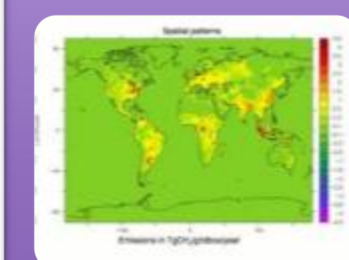

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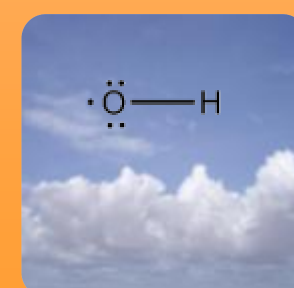


CH_4 Inventories: EDGAR v4.2 extended till end 2012

- Emission Database for Global Atmospheric Research (EDGAR V4.2)

CH4 emissions by country and main source category for the period 1970-2008 (EDGAR v4.2_EM_CH4_300911 - free download at http://edgar.jrc.ec.europa.eu/datasets_list.php?v=42)

- Update for the period 2009-2012 based on:

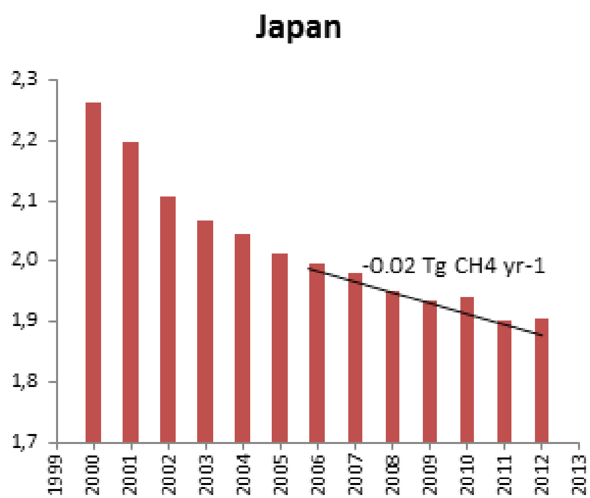
(i) FAO Statistics of CH4 emissions from enteric fermentation, manure management and rice cultivation http://faostat3.fao.org/download
(ii) BP Statistical Review of fugitive emissions of CH4 from solid fossil fuels, fugitive emissions from oil and gas http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy/statistical-review-downloads.html

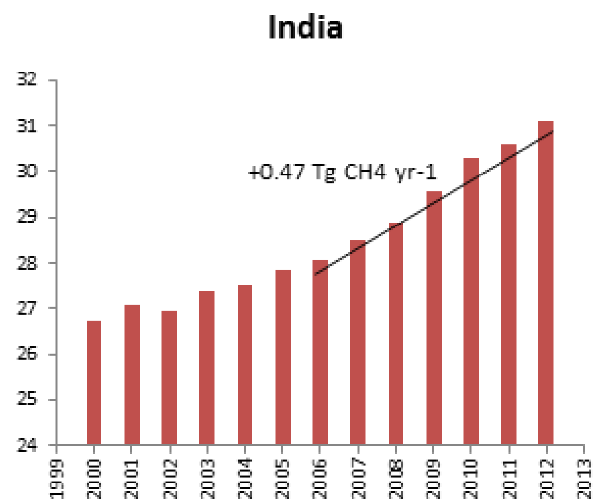
Conversion factor applied to access CH4 emissions in each main source category exist in FAO or BP Statistics with equation:
CH4 emissions (Year N) = (mean 2006_2008 (EDGAR / FAO)) x FAO(Year N)

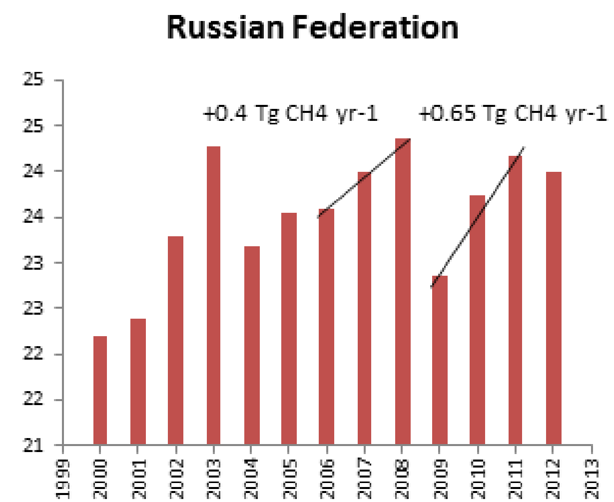
Otherwise, CH_4 emissions of 2009-2012 remain stable at level of 2008.

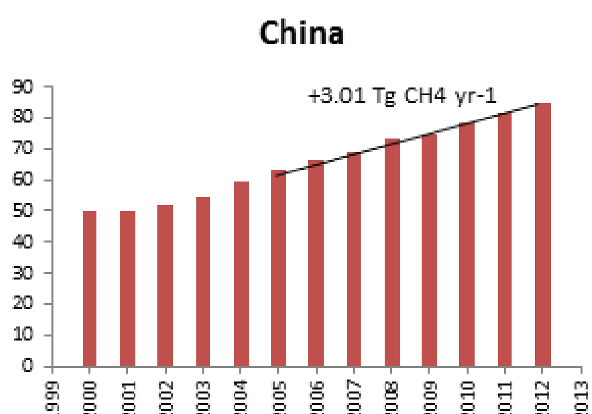
CH_4 Inventories: EDGAR v4.2 extended till end 2012

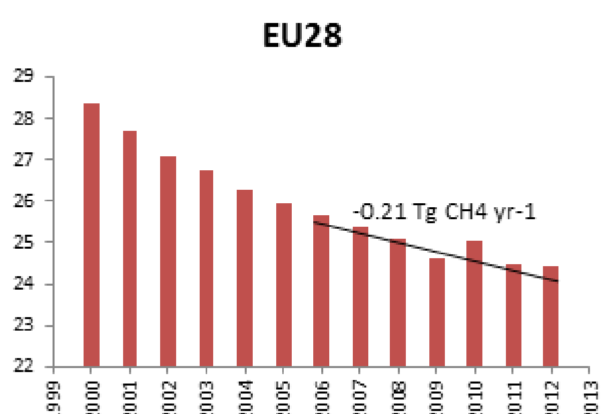
Country scale

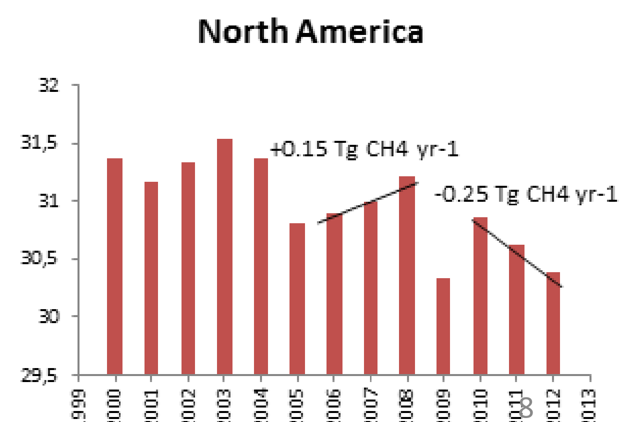






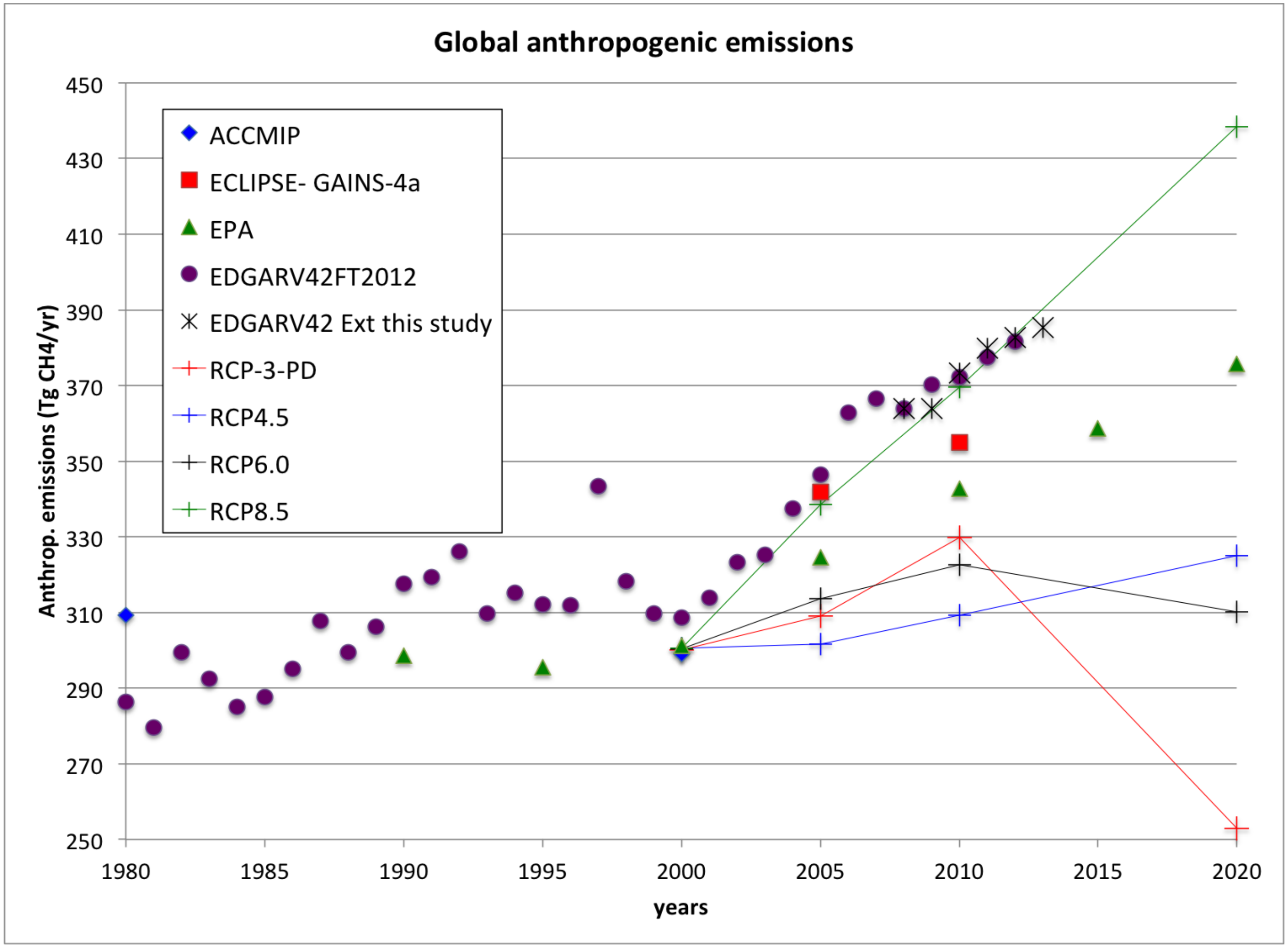






CH$_4$ Inventories: EDGAR v4.2 extended till end 2012

Time evolution of global anthropogenic emissions



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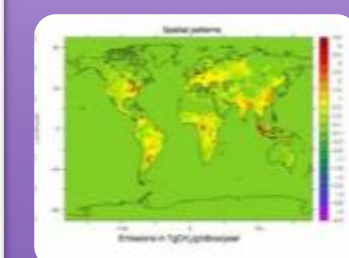

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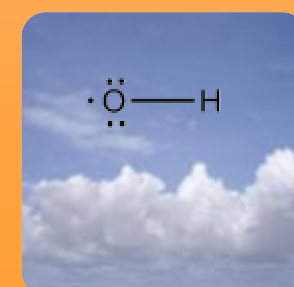
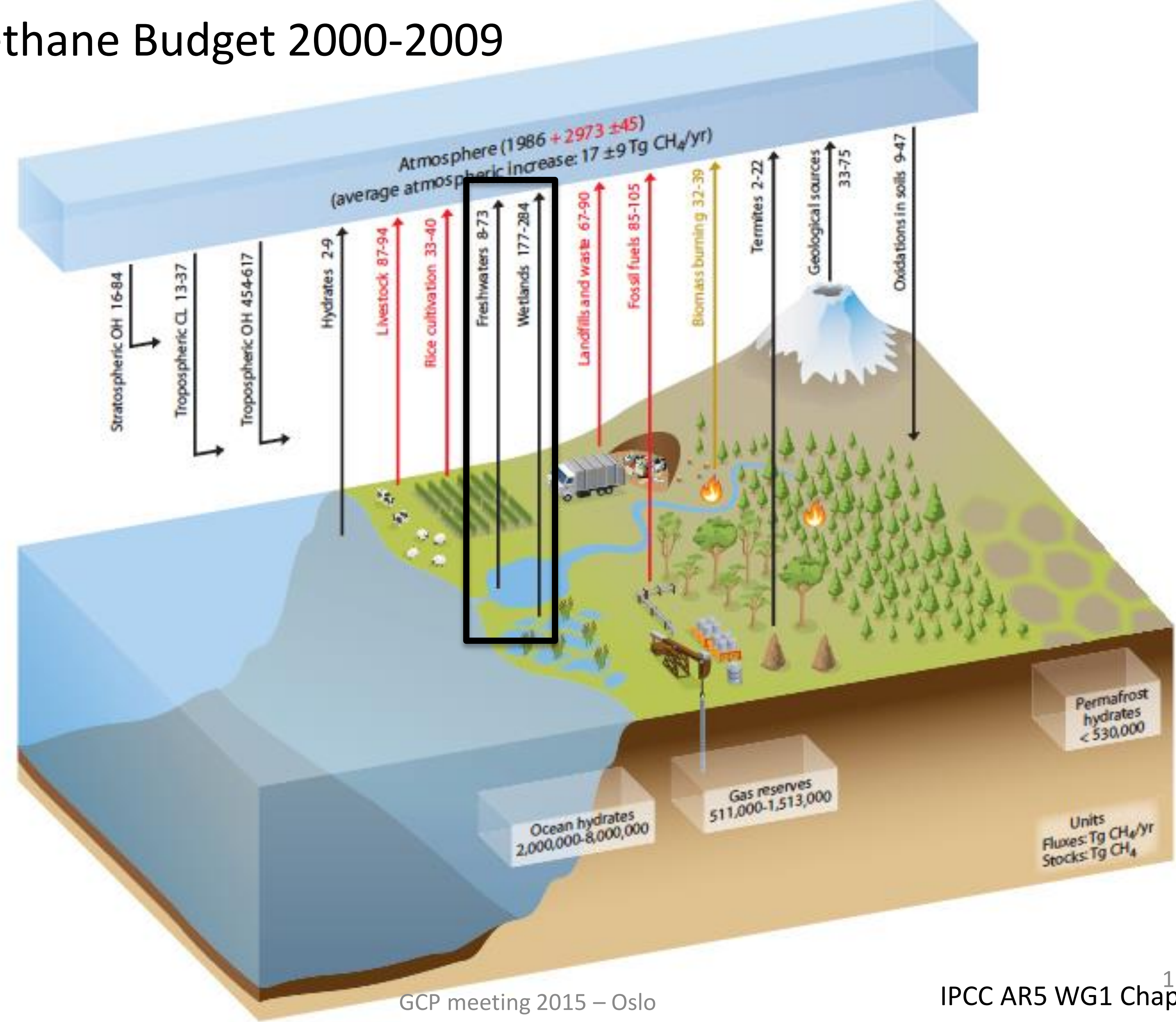


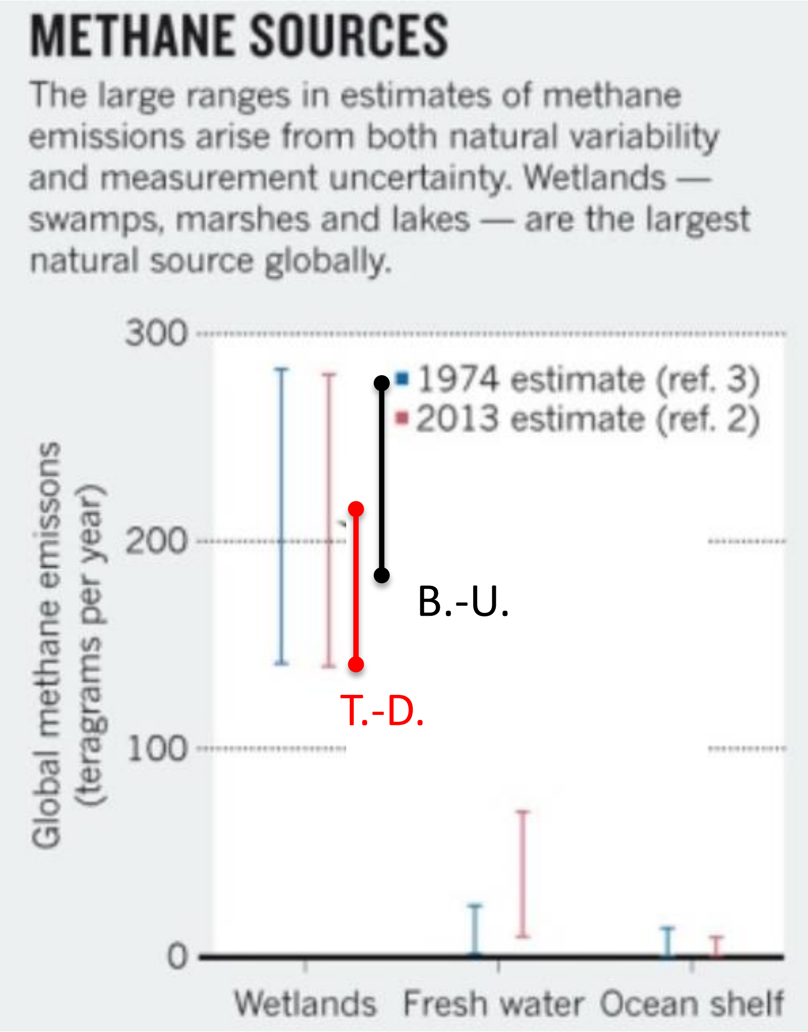
Global Methane Budget 2000-2009



IPCC AR5 WG1 Chapter 6

Wetland CH$_4$ production processes

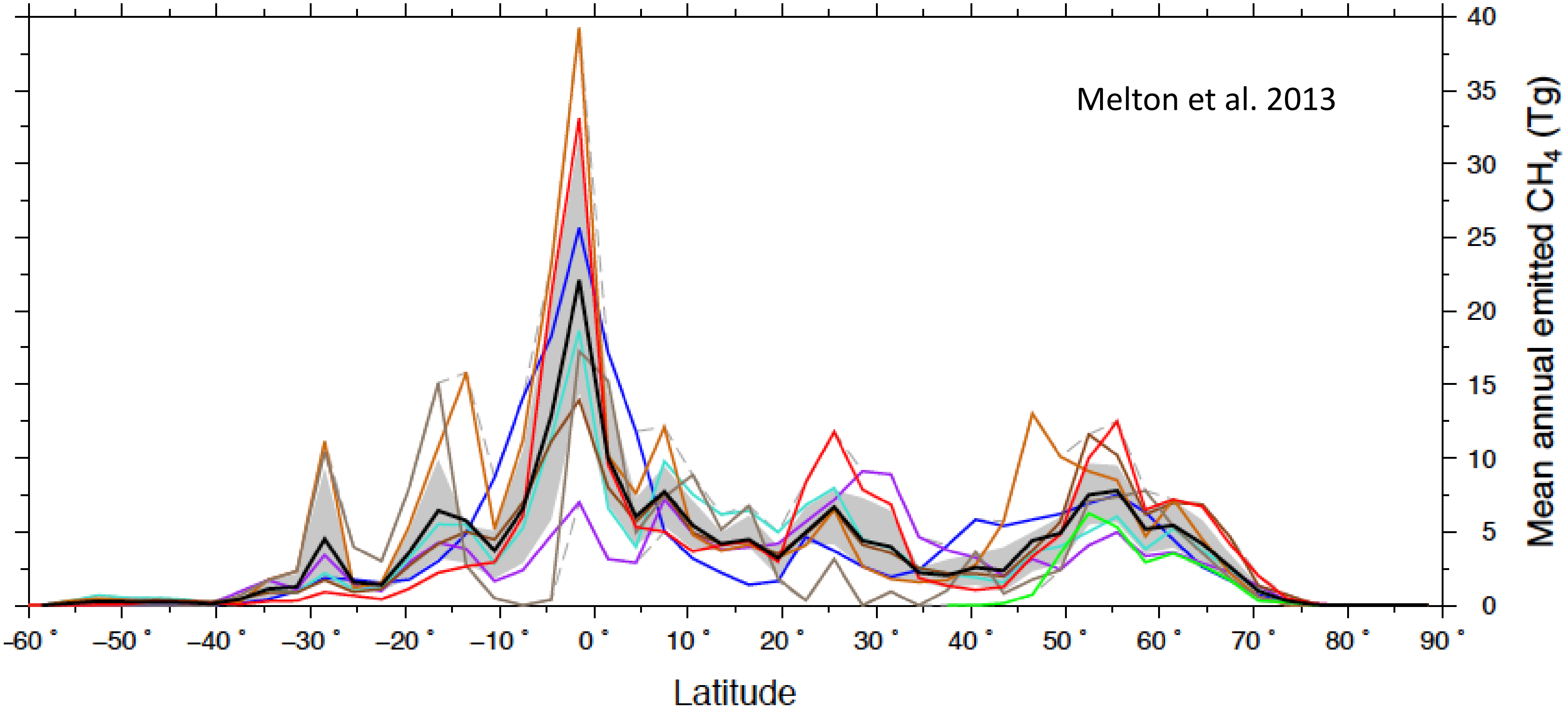
- Christensen approach is used in all 'process-based' models used today



Christensen 2014

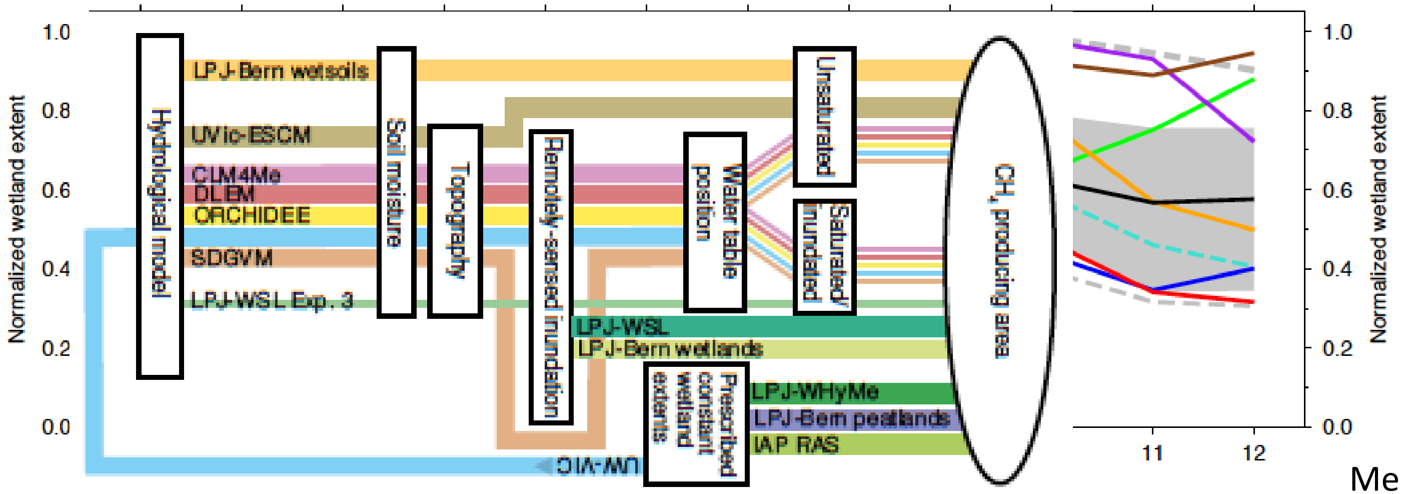
A look at wetlands:

- WETCHIMP (Melton et al. 2013, Wania et al. 2013)
- Ten wetland models (“bottom up” / forward models)
- Common protocol for climate & varying protocol for wetland extent



WETCHIMP (Melton et al. 2013, Wania et al. 2013)

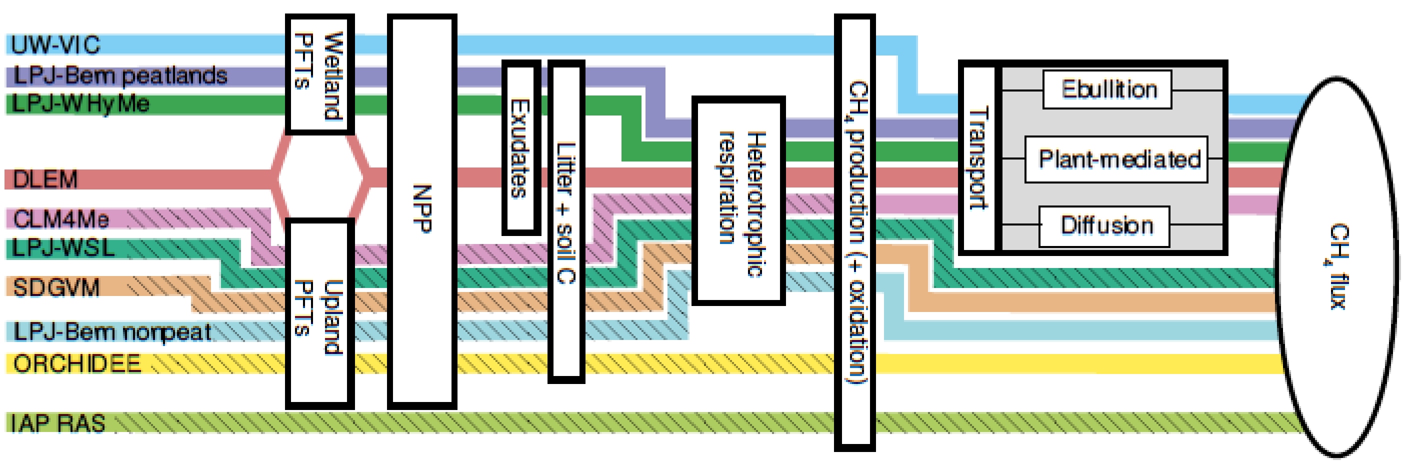
- Range of uncertainty due to wetland extent



Melton et al. 2013

Wania et al. 2013

- … and structural differences



Global Carbon Project CH_4 budget update

- Comprehensive update to 2012 of sources and sinks
- Continuation of WETCHIMP protocol for wetland emissions
- All using satellite-derived wetland area
- Wetland area (excluding rice)
  - Seasonality
  - Detection

RADAR and Wetlands : GIEMS product

- Passive & active microwave
- Flooding decreases emissivity
- Sensitive to rain/clouds/vegetation
- Coarse resolution (25-50 km)

Until 2007 only !

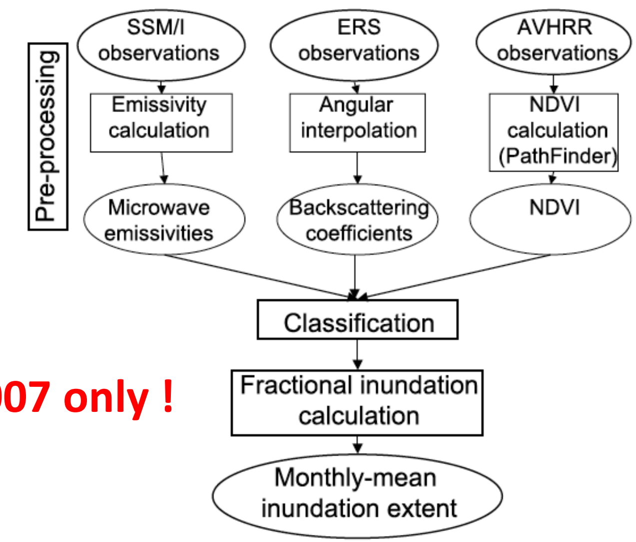


Figure 1. Schematic representation of the multisatellite method to estimate wetland extent.

Prigent 2007, Papa 2010

Global Carbon Project CH$_4$ budget update

- New NASA “SWAMPS” product to extend wetlands data to 2012
  - 25 km resolution
  - 15-day cycle

Exemple of Siberian lowlands

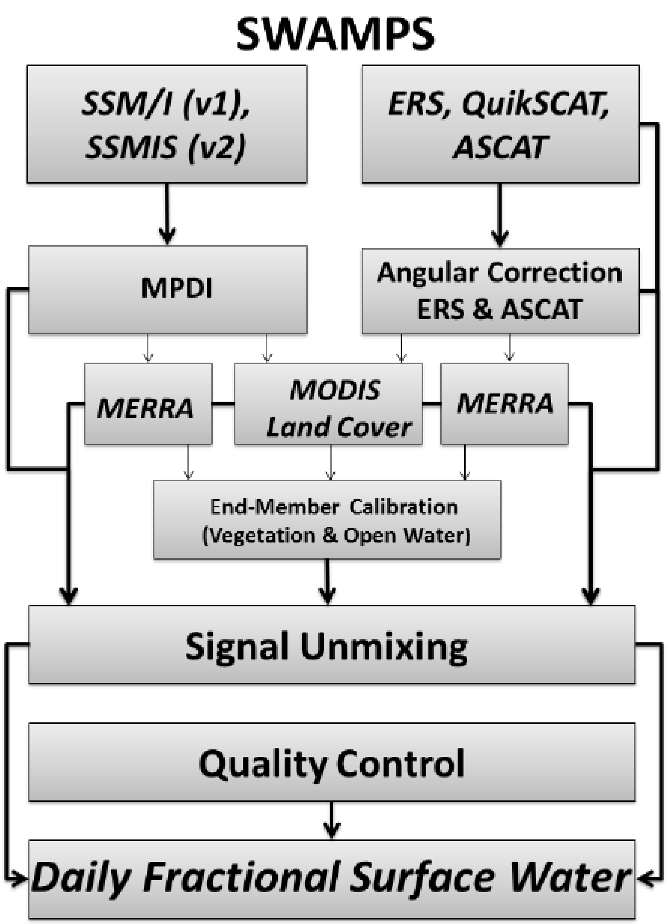
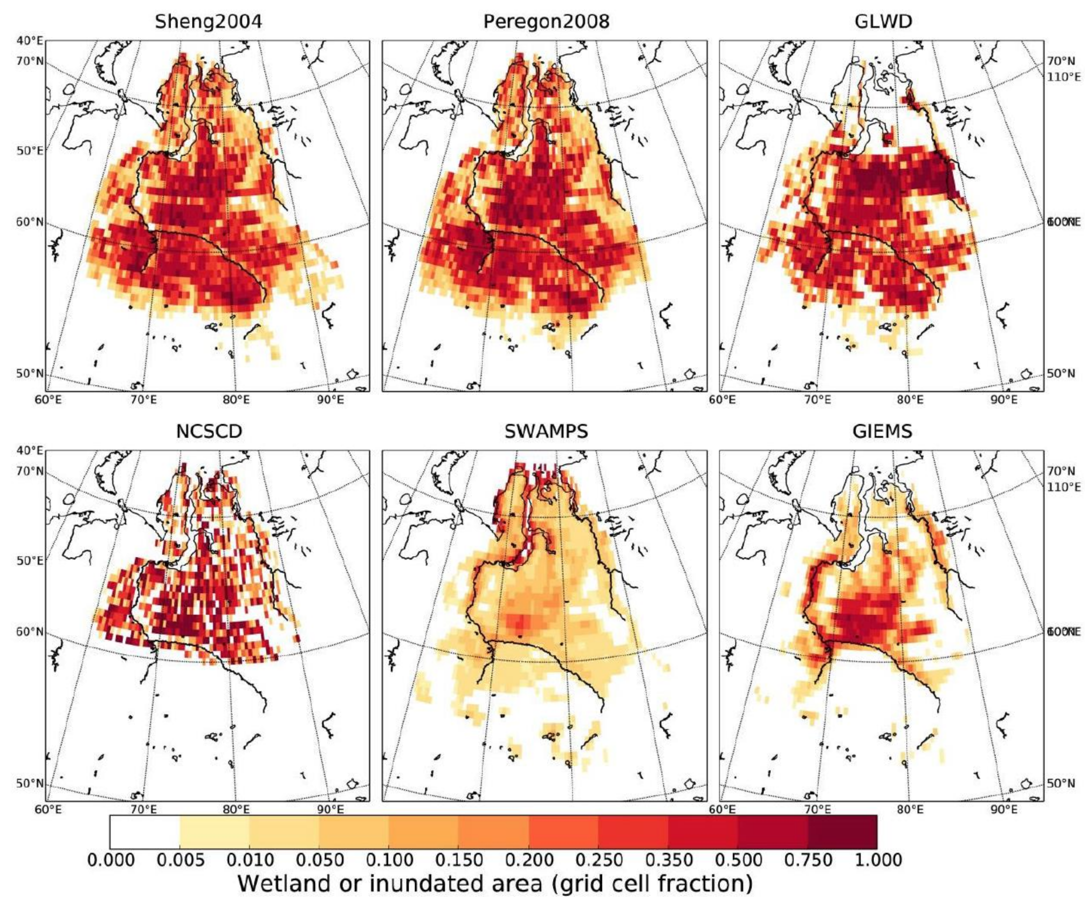


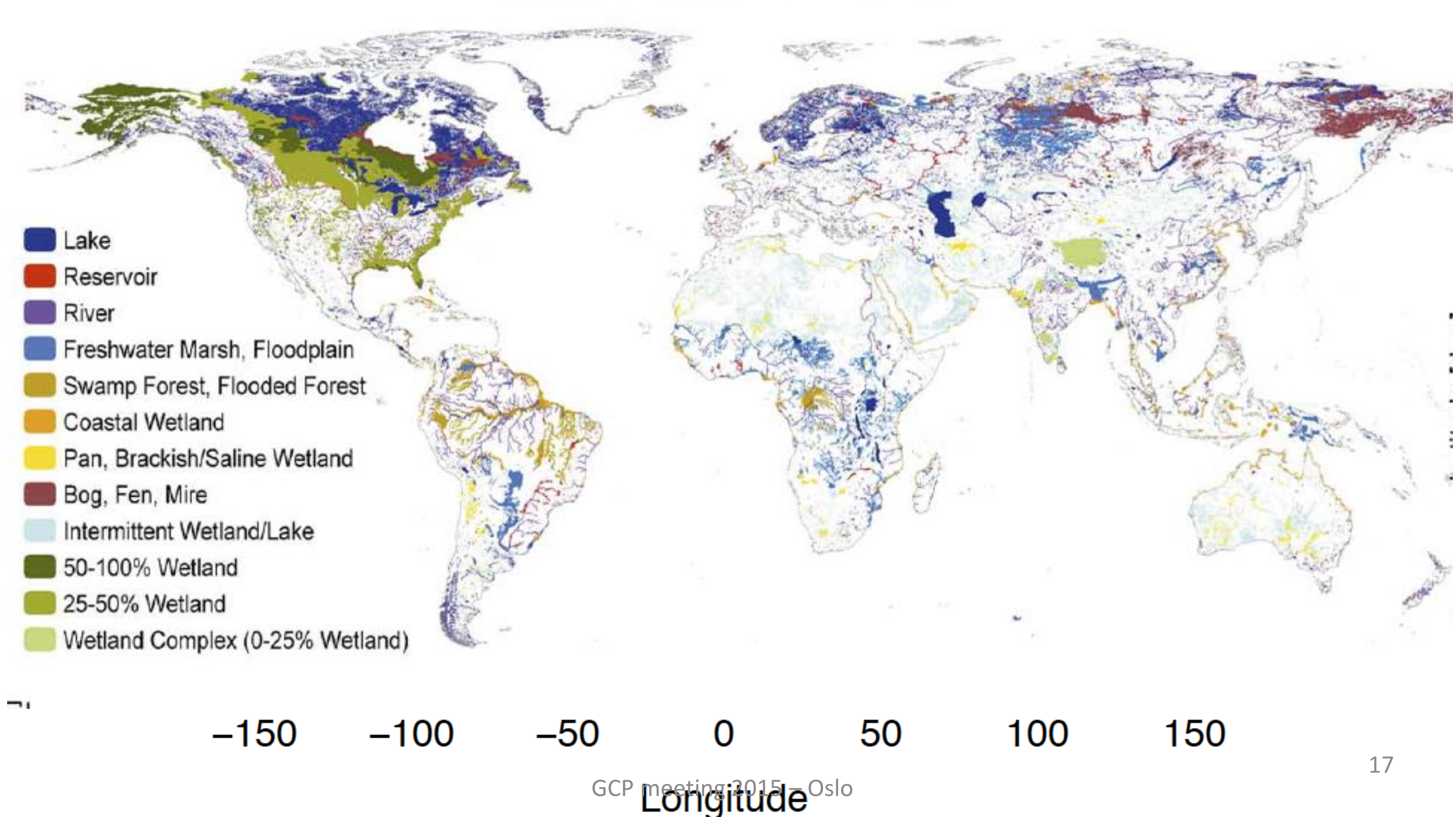
Figure 1 Flow chart of the SWAMPS surface water fraction retrieval scheme including the calibration of vegetation and open water end-members and post-product quality control (QC).



Bohn 2015

Global Carbon Project CH$_4$ budget update

- SWAMPS merged with GLWD (Lehner and Doll 2004, Kassel Univ. Germany)
  - $SWAMPS_{GLWD}=GLWD_{x,y}*SWAMPS_{x,y,m}/SWAMPS_{x,y,ymax}$
  - Inventory 8.7 Mkm^2 (excluding rivers, lakes, reservoirs)



Version 1.5 January 16th, 2015
Version 1.0 April 23rd, 2014

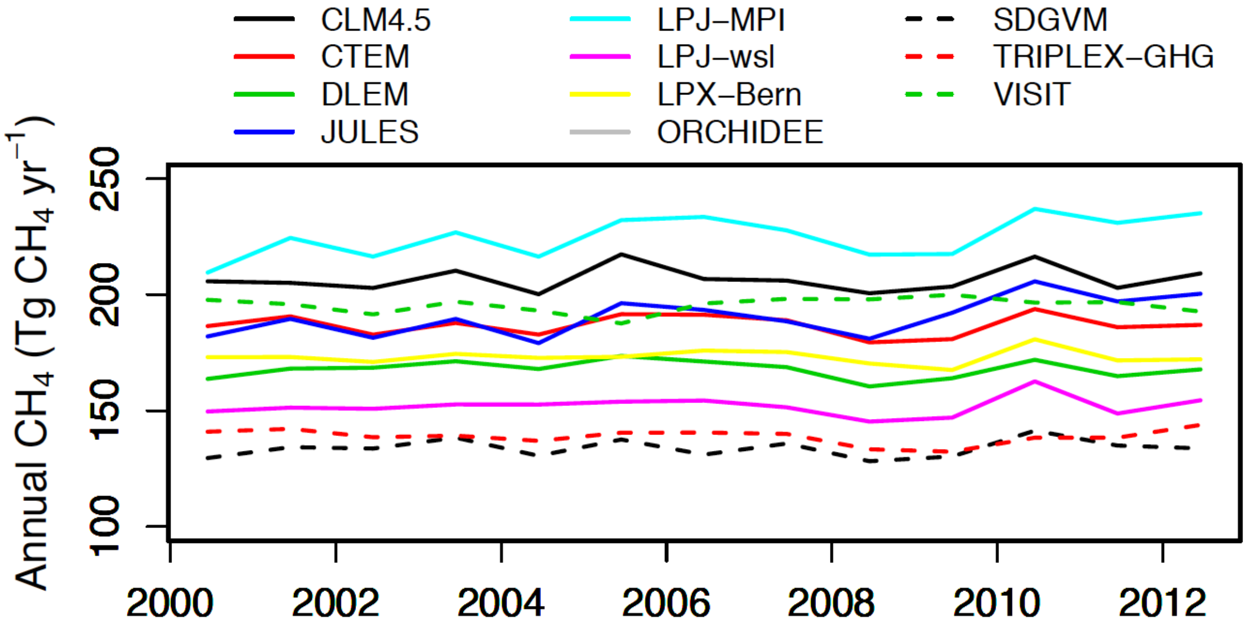
Protocol for natural wetland CH_4 emission modeling
Contacts: benjamin.poulter@montana.edu, philippe.bousquet@lsce.ipsl.fr and pep.canadell@csiro.au

REVISED Deadline for submission of simulations: February 15th, 2015

177 TgCH_4/yr [133 – 224]

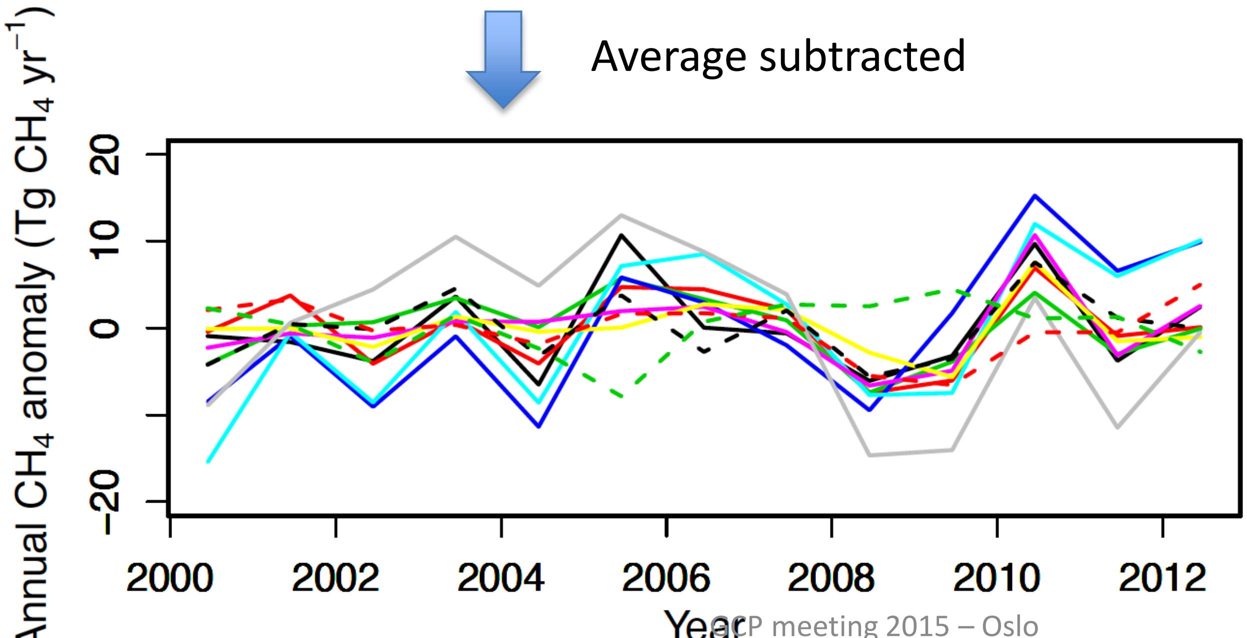
Average Annual Wetland CH_4 Emissions (2000-2012)

Model Name	Global	<30°N	30-50°N	>50°N
CLM4.5	206.7±5.4	122.9	29.3	54.4
CTEM	186.9±4.4	116.1	29.7	49.2
DLEM	167.9±3.8	122.9	19.5	28.7
JULES	190.5±8.2	114.2	10.6	64.9
LPJ-MPI *	224.9±8.7	113.9	27.8	83.2
LPJ-wsl	151.9±4.3	125.6	7.7	18.6
LPX-Bern	173.2±3.2	124.4	21.1	27.7
ORCHIDEE	173.0±9.4	135.7	10.6	26.7
SDGVM	133.8±3.8	69.6	24.1	40.0
TRIPLEX-GHG	138.9±3.2	84.6	30.1	24.2
VISIT	195.5±3.4	121.9	30.2	43.4
Mean	**177±40**	**114±35**	**22±8**	**42±9**



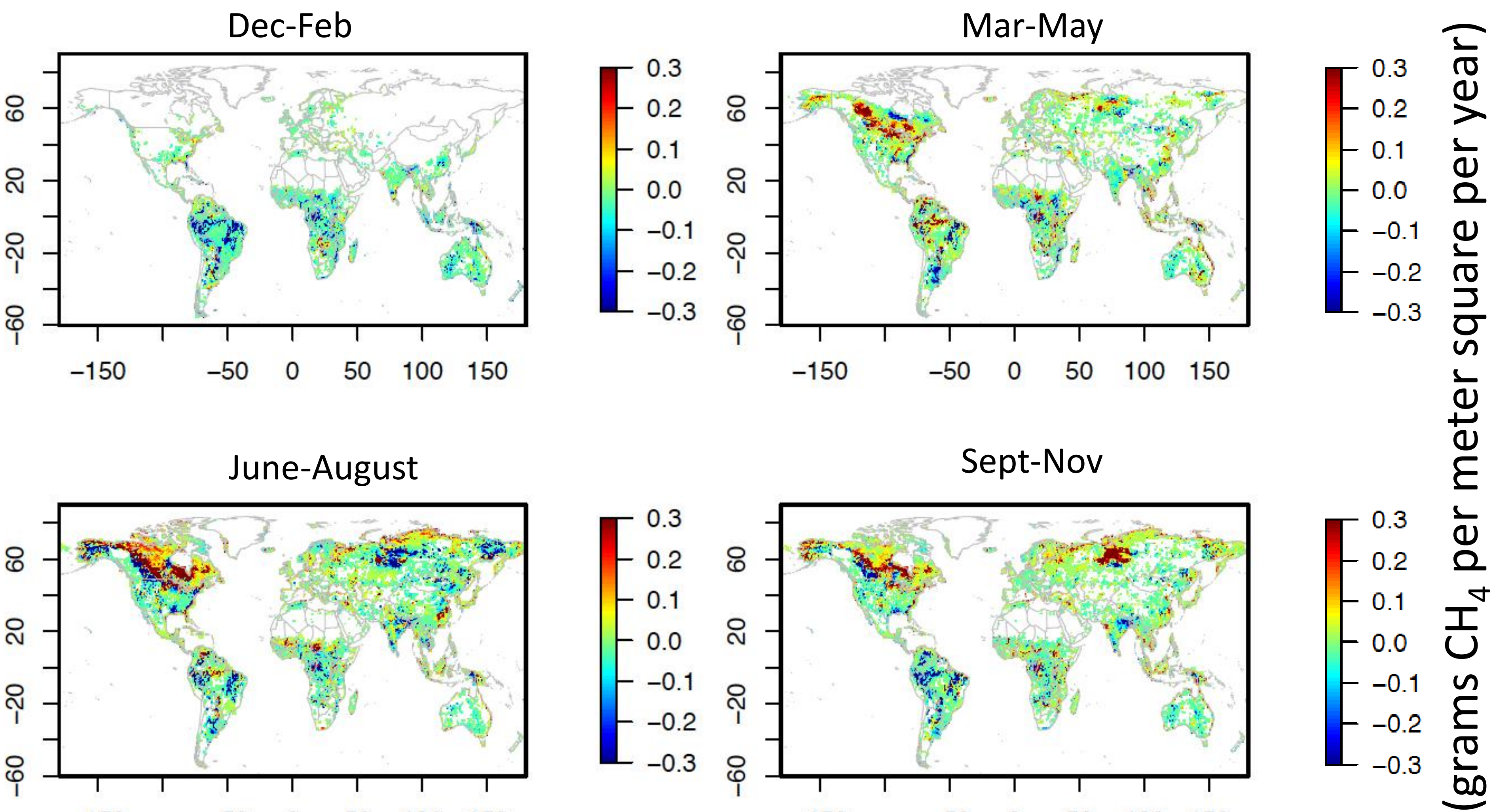
Evolution of Global CH$_4$ total emissions

Average subtracted



Evolution of Global CH$_4$ anomalies

Trends in seasonal wetland CH$_4$ emissions (2000-2012)



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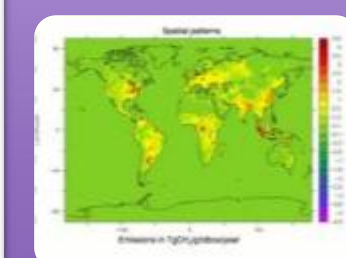

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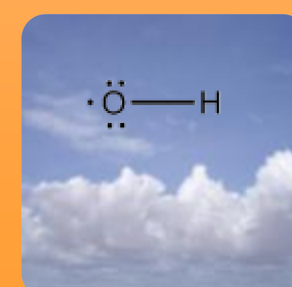
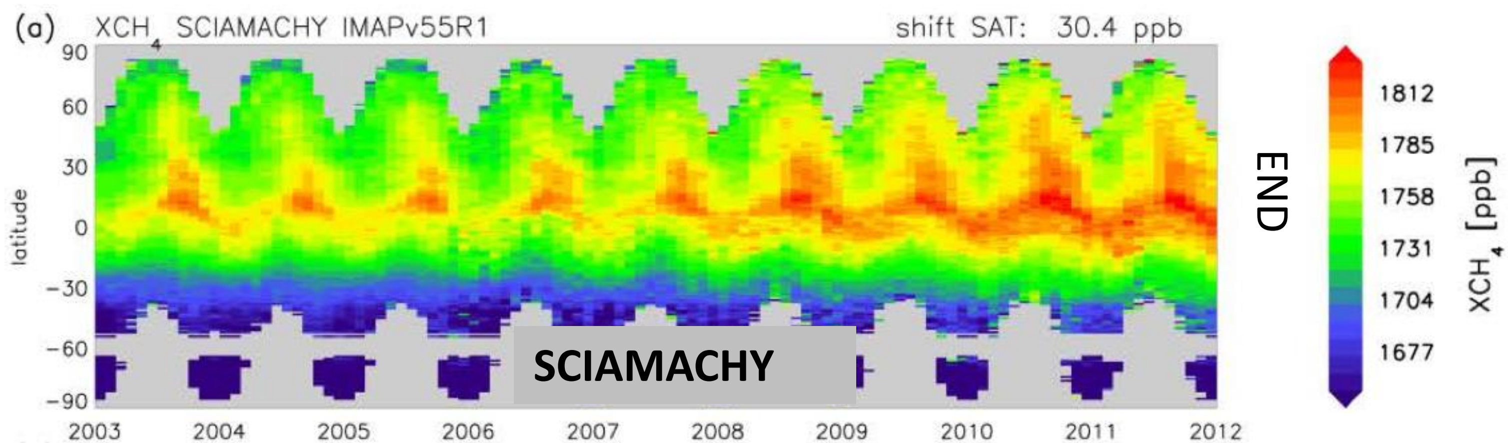
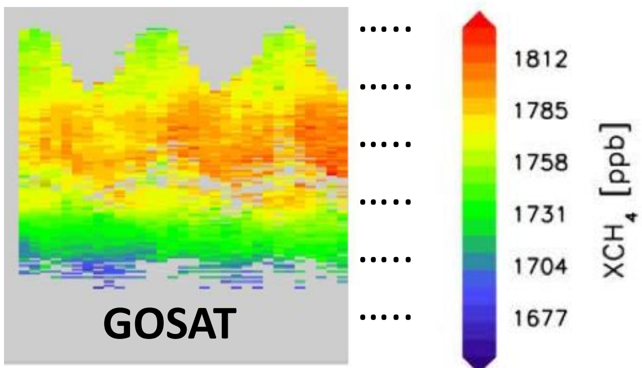
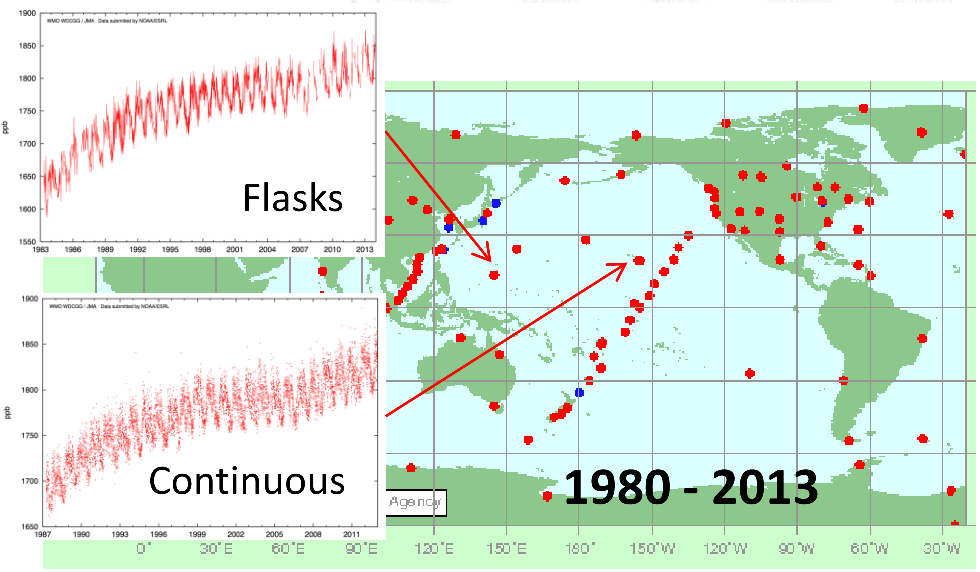


Surface and satellite data





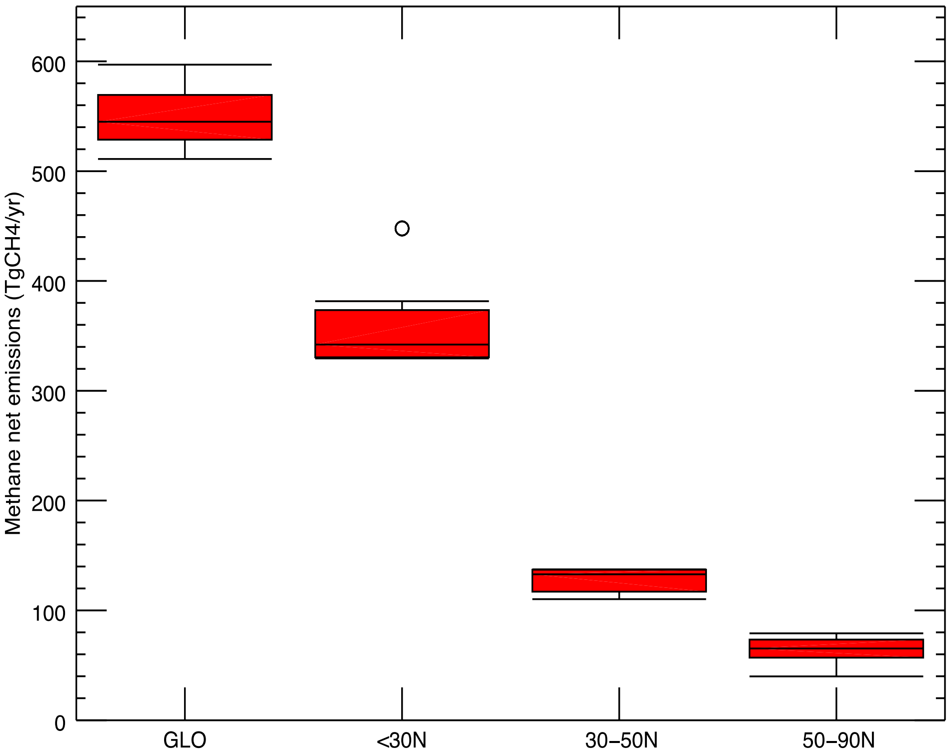
Source : P. Bergamaschi,
http://www.esa-ghg-cci.org/index.php?q=webfm_send/153



Source : World Data Center for Greenhouse Gases,
http://ds.data.jma.go.jp/gmd/wdcgg/cgi-bin/wdcgg/map_search.cgi

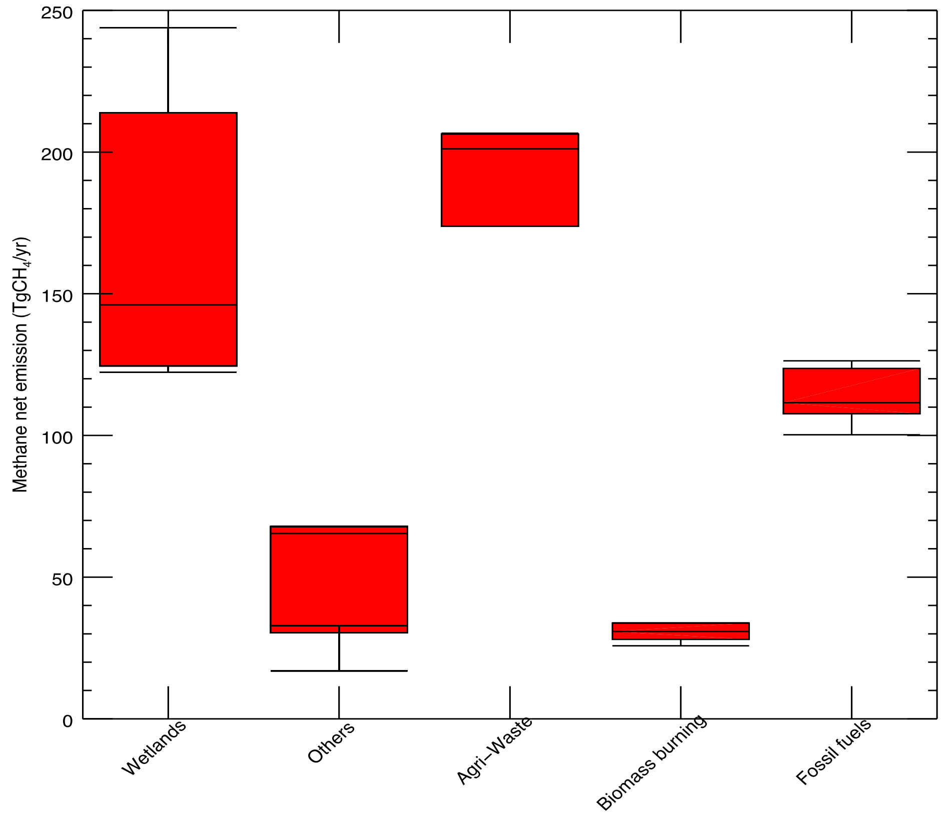
+ IASI (TIR)
+ Aircraft data
+TCCON

Global & latitudinal budget (2012)



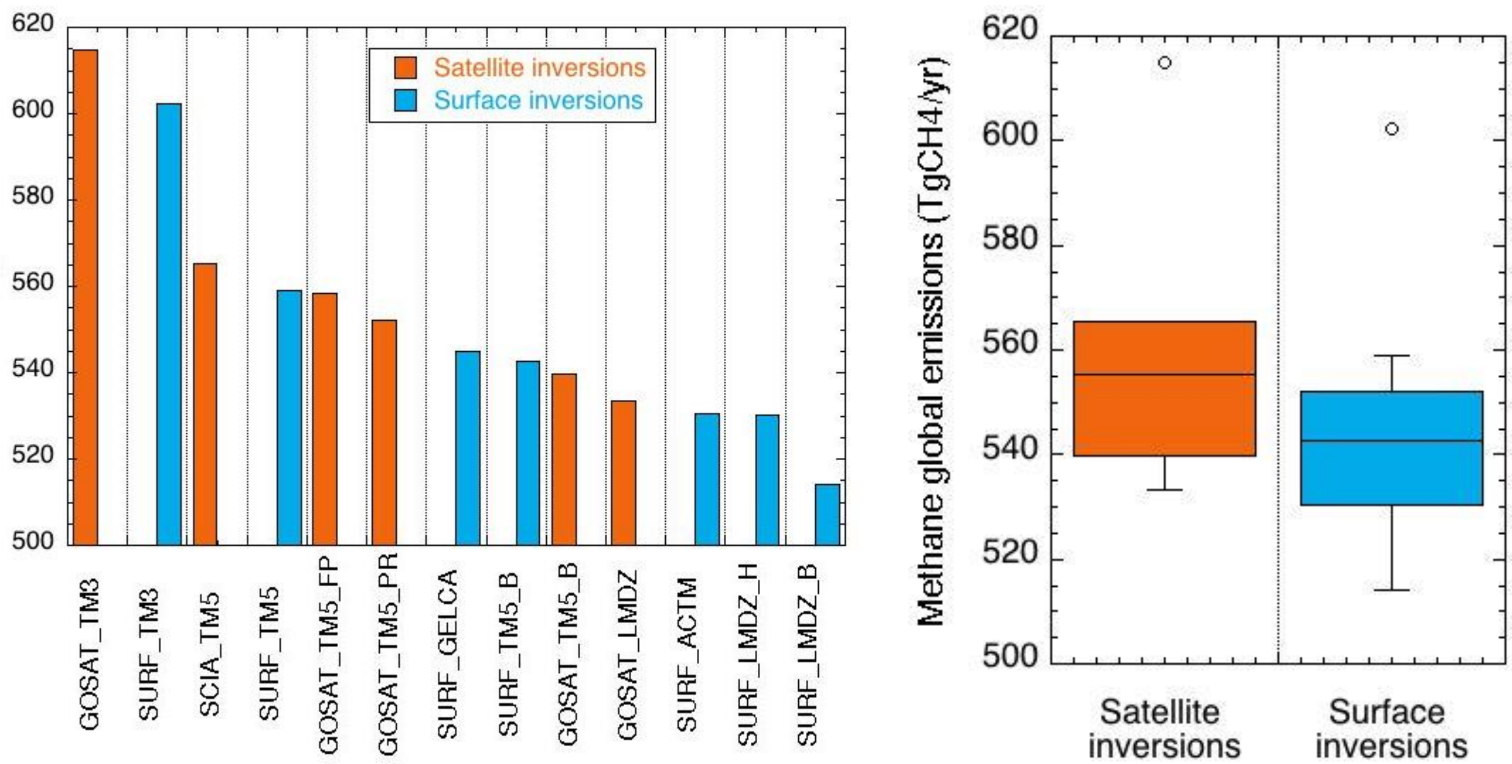
Global and latitudinal budget for year 2012. Each box plot represents the range of the top-down estimates inferred by the ensemble of inversions. Median value, first and third quartiles are presented in the box. The whiskers represent the minimum and maximum values when outliers are removed (3σ).

Global budget per source category (2012)



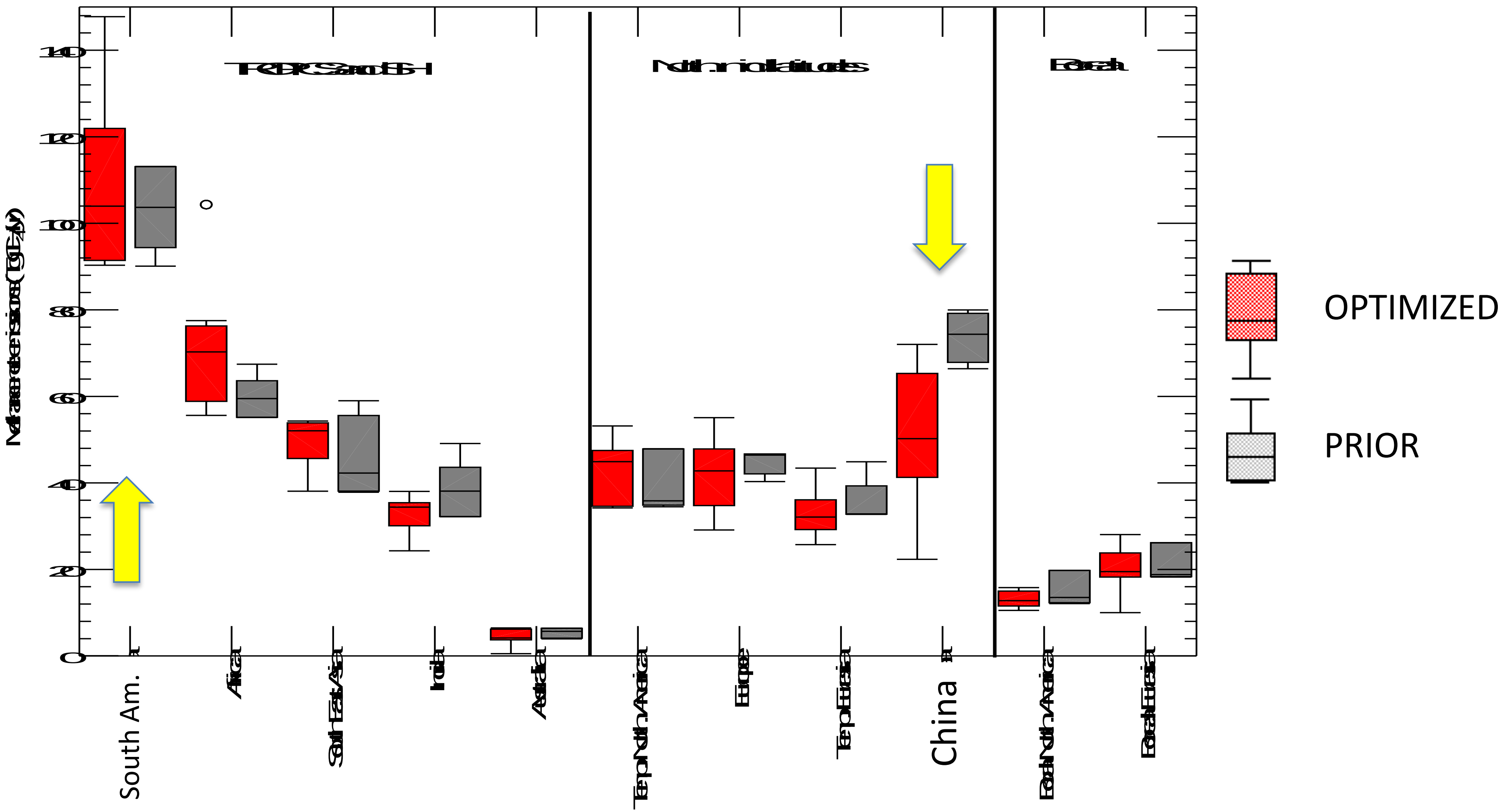
Methane global emissions by category for the year 2012 (not all models provided category splitting yet)

Can we distinguish satellite and surface based inversion ?



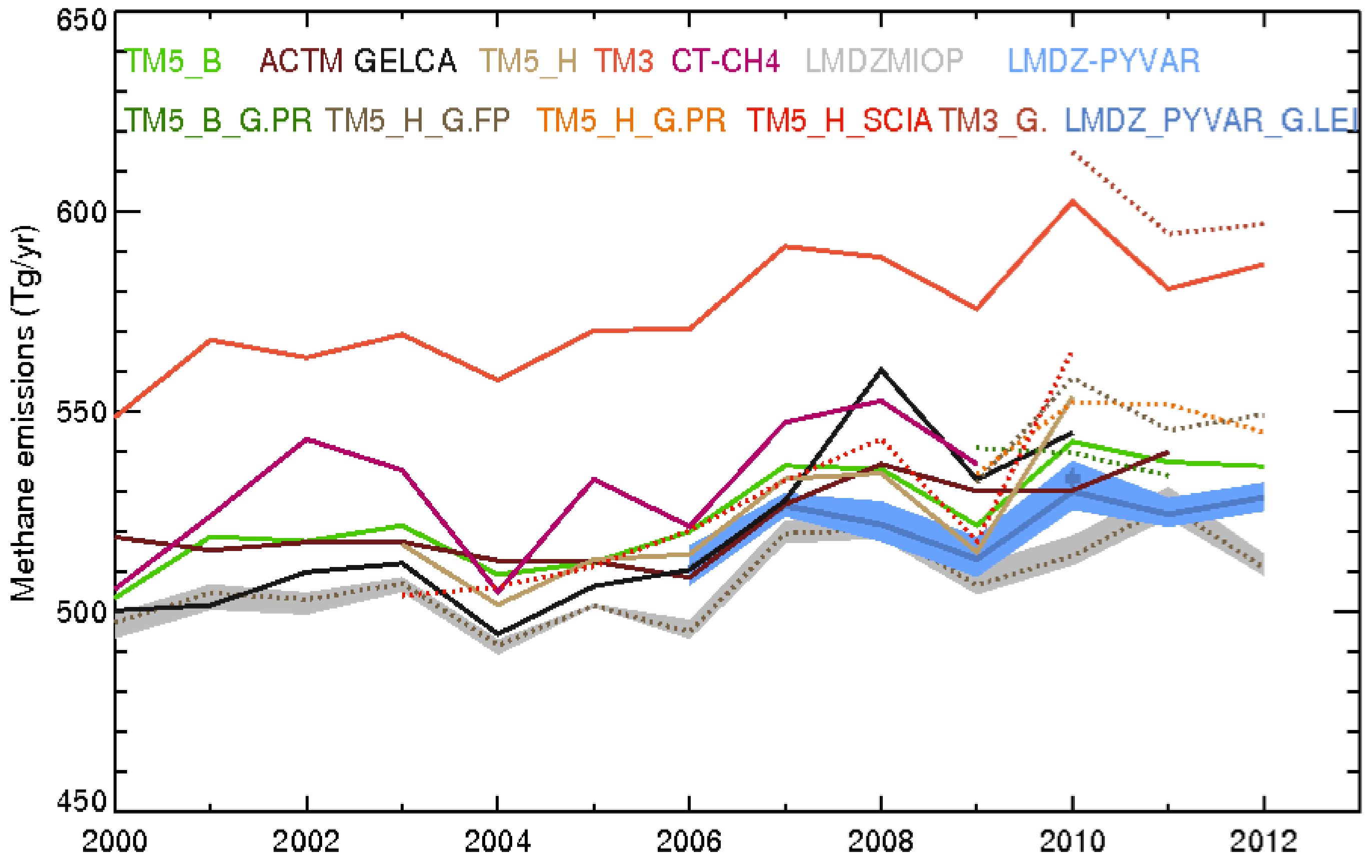
- (Non significant) larger global methane emissions inferred by satellite based inversions (~+10 TgCH$_4$/yr)
- BUT : larger difference exists between models

Regional budget

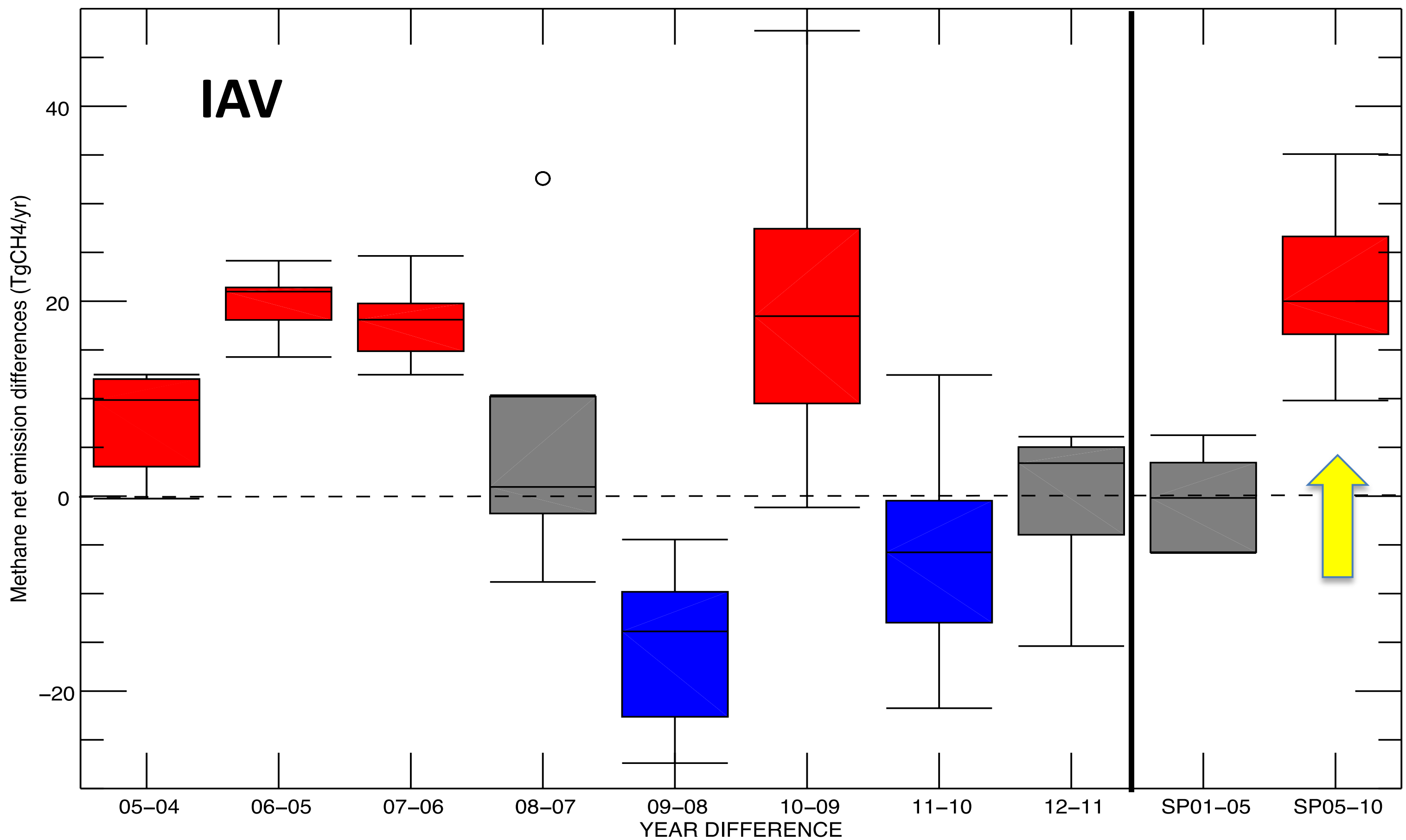


Posterior (red) and Prior (grey) regional estimates of the methane budget in 2012, in Tg/yr.

Evolution of global net emissions with T-D inversions



Comparison of the global methane emissions derived from the different inversions included in this paper. Surface based inversions are in solid line, upper legend; satellite based inversions are in dotted line, lower legend



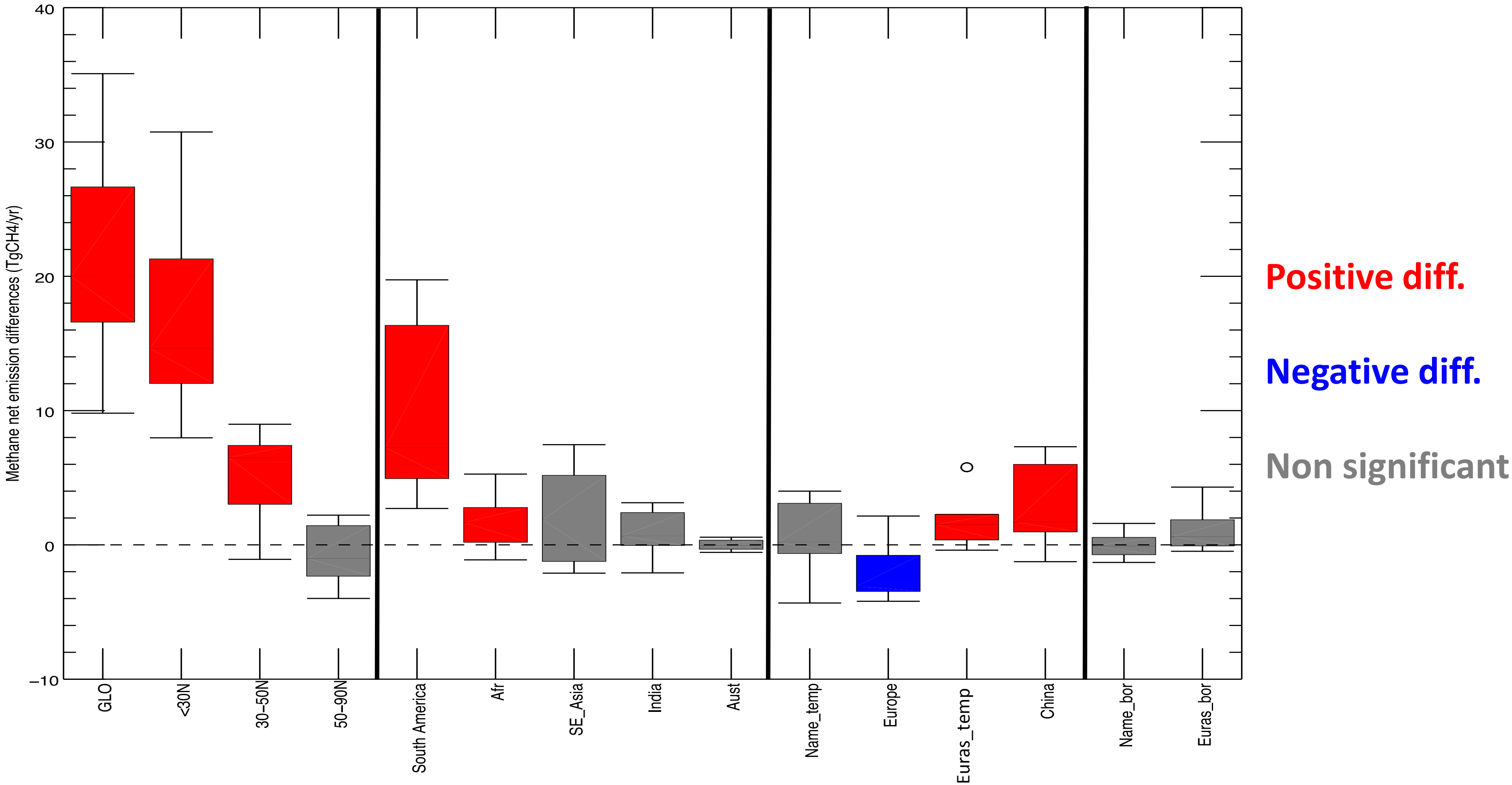
Positive diff.

Negative diff.

Non significant

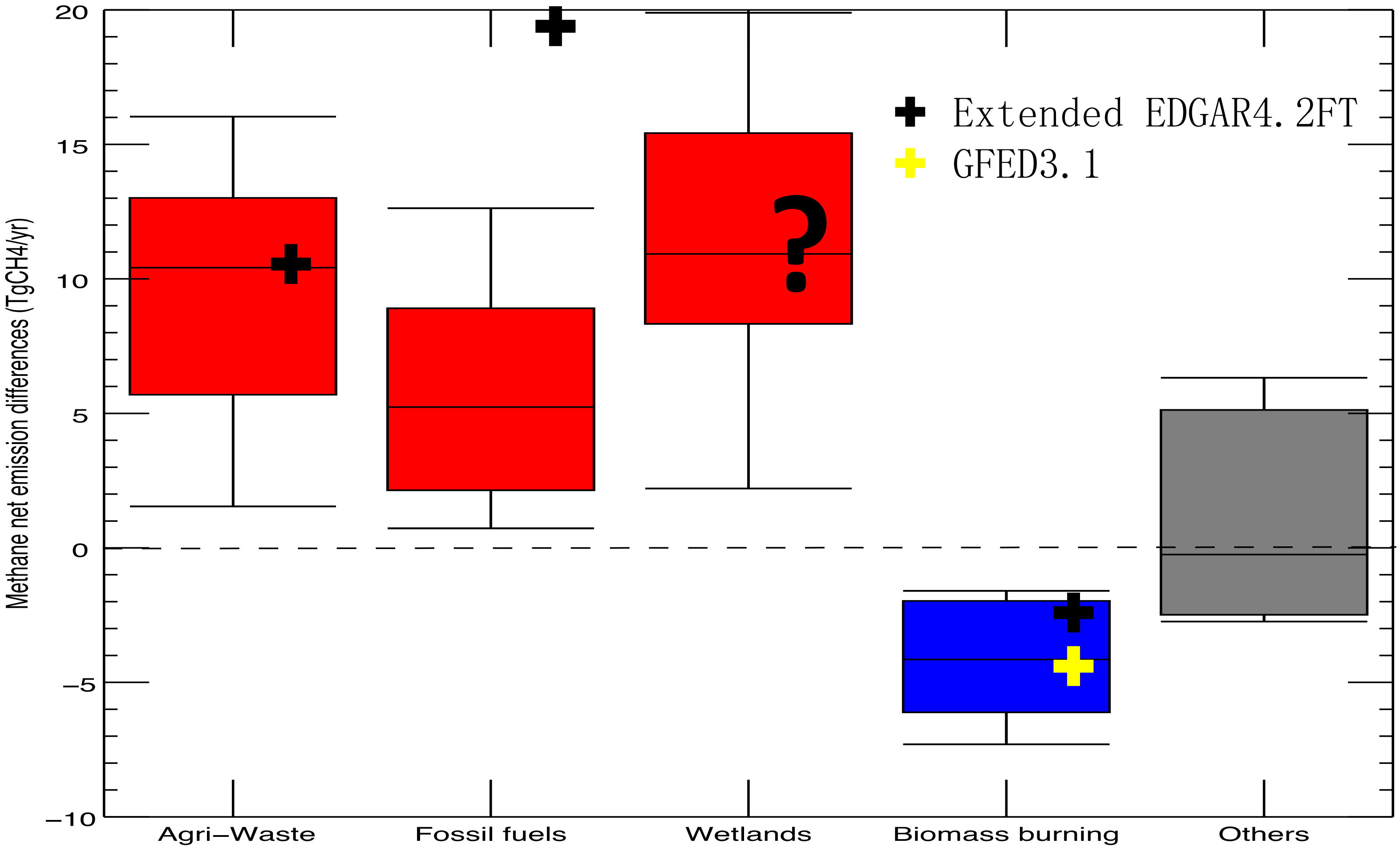
Year to year differences in global methane emissions presented as boxplots. the last two boxplots show the difference between the years 2004-2006 and the years 2000-2002 and between the years 2011-2009 and 2004-2006.

Regions contributing to 2010-2005 difference in emissions



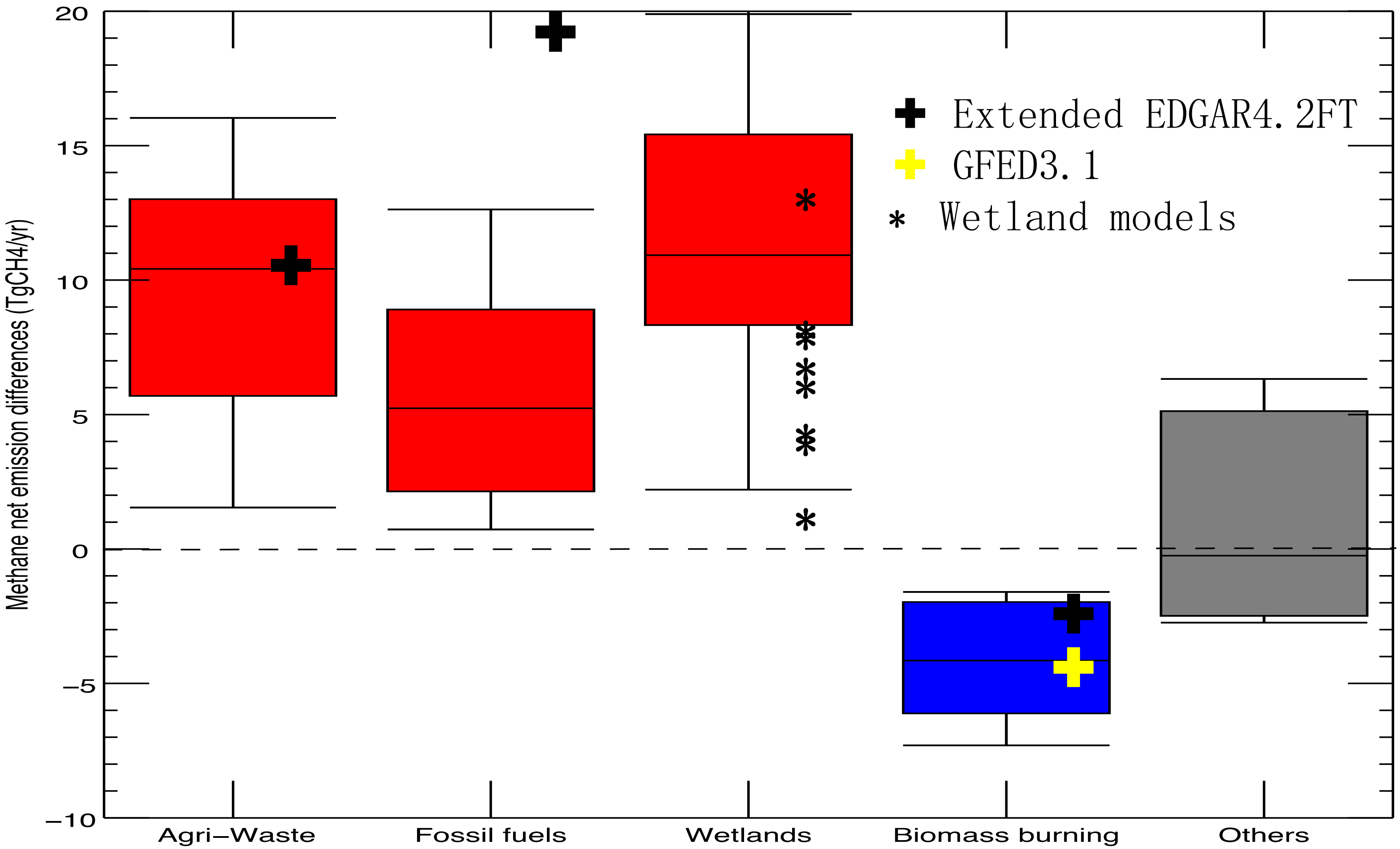
Difference in methane emissions between the year 2010 (as the period 2009-2011) **and the year 2005** (as the period 2004-2006) in Tg for all regions.

Source categories contributing to 2010-2005 difference



Contribution by emission categories to the global positive change between the year 2005 (as the period 2004-2006) and the year 2010 (as the period 2009-2011), in Tg/yr

Source categories contributing to 2010-2005 difference



Contribution by emission categories to the global positive change between the year 2005 (as the period 2004-2006) and the year 2010 (as the period 2009-2011), in Tg/yr

Some challenges to conclude :

- 2007 rise in CH_4 concentrations continues. Attribution is complex : Natural / Anthropogenic sources, Chemical sinks (CCMI 2015 to come)
- Reduction is wetland model spread not guaranteed on the short term. More work needed.
- Top-down atmospheric inversions can provide insights on :
  - Global IAV in emissions
  - Global & hemispheric total emissions & trends
  - Regional total emissions & trends
  - Global emissions per source type
  - Regional emission per source type

Decreasing confidence

- Chinese methane emissions and trends are found significantly smaller than in EDGAR4.2.
- The 2005 to 2010 change in methane emissions is estimated at 20 Tg/yr, with comparable contributions from anthropogenic and natural emissions.
- **Asian GHG budget inter-comparison activity ongoing (P. Prata, R. Thompson, et al.)**
- **Global methane leakage assessment (R. Jackson)**