Towards a routine update of the CH_4 global budget

GCP SSC Meeting – Methane Session

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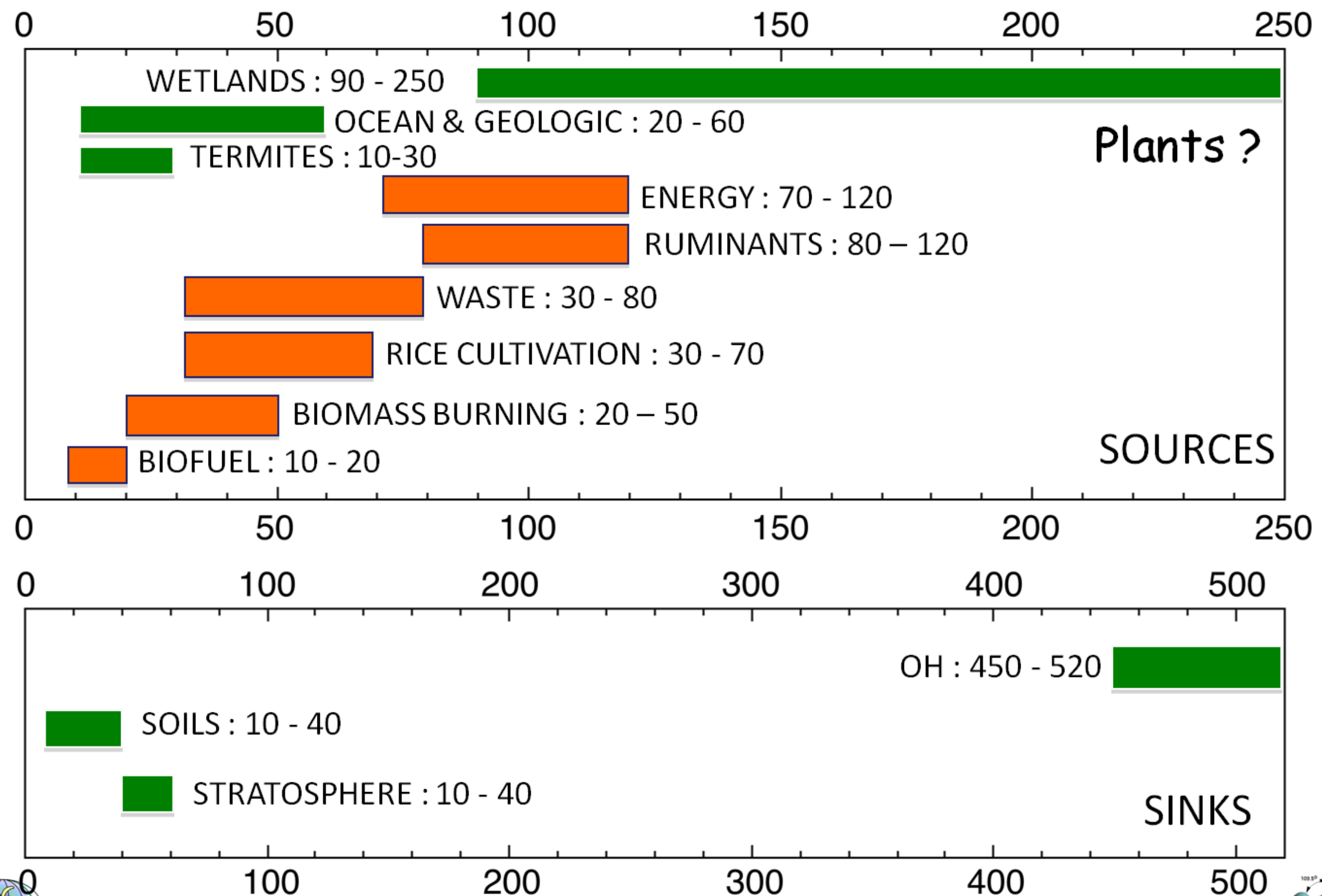
Quick Intro

- CH_4 – one of the most important radiatively active trace gases
- Rapid rise in atmospheric concentrations since start of records in 1978 (0.8-2% y^{-1})
- Signs of decline in the 1990's, near-zero growth
- 2007/2008: increase in globally averaged atmospheric CH_4

Methane sources and sinks for the past two decades ($TgCH_4\ y^{-1}$)



Courtesy
P. Bousquet

Current Status & Need for Improvements

- Inventories (e.g., EDGAR) are not updated on an annual basis (?)
- Observations/observation networks are not updated regularly → can we provide a structure?
- Limited links with vegetation/CH_4 emission models (How to establish?)
- Limited linked observations at different scales (How to establish?)

Making the CH_4 global budget update more operational

- *Activity 1:* collect bottom-up flux data and atmospheric data to close the global CH_4 budget for different time periods
- *Activity 2:* compile available inversion flux data + error/uncertainties, produce annual update of CH_4 inversion fluxes/provide global top-down estimates of CH_4 emissions
- *Activity 3:* provide a product: estimated CH_4/optimized atmosphere

Making the CH_4 global budget update more operational

- Activity 1:
  - 1. Historical period (1850-1980)
  - 2. The high growth rate period (1980-1990?)
  - 3. The low growth rate period (1991-2006?)
  - 4. The recent anomaly (2007-ongoing)

→ Historical and modern global budget
  - Global total flux
  - Global error
  - Spatio-temporal distribution

Making the CH_4 global budget update more operational

- Historical Period:
  - Compile evolution of the mix of different sources from literature/references
  - Use model estimates of OH fields (e.g., Prinn et al., 1995; Chen and Prinn, 2005; Chen and Prinn, 2006; Krol et al., 1998; Krol et al., 2008)
  - Use ice core data (smoothed) for atmospheric CH_4 obs
  - Does a similar smoothing need to be applied for other sources/the OH sink?
  - How can uncertainties be estimated? Expert judgment? Use of different estimations?

Making the CH_4 global budget update more operational

- The high growth rate and low growth rate periods:
  - Is the CH_4 cycle in equilibrium (i.e. sources in balance with sinks) on the long term, or do we observe opposing trends in different sources (e.g., as suggested in Bousquet et al., 2006)?
  - What is the role of the recent emissions increase of fossil CO_2 on the CH_4 growth rate?
  - What is the role on recurrent drought on wetland and fire emissions?
  - What is the role of OH fluctuations on the CH_4 growth rate?
  - How can we better constrain emitting regions?
  - What is the role of processes like eruption of Mt. Pinatubo (1991), collapse of former USSR?

Contemporary budget 1980-1990

Component	Historical reconstructions/ inventories	Inversions
Growth rate	Atmospheric data NOAA-ESRL	
Global OH	Model results (e.g., Prinn et al., 1995; Krol et al., 1998; Bousquet et al., 2005), Dentener 2003	See table 4 +optimization
Global fires	Mouillot et al., 2006(20th century); Stern and Kaufmann, 1998	See table 4 (+GFED, G Van der Werf +optimization)
Wetlands (drained?)	Matthews and Fung, 1987 Circumpolar wetlands: Wania et al., 2004; Wania et al., 2010 (diss.)	See table 4 +optimization
Fossil	Marland et al., 2008	See table 4 +optimization
Coal mines/gas	Marland et al., 2008; Stern and Kaufmann, 1998	See table 4 +optimization
Rice	<1961: C Granier; N Ramankutty; JF Soussana; B Dorim; Stern and Kaufmann, 1998 >1961: FAO; Stern and Kaufmann, 1998	See table 4 +optimization
Livestock/ruminants	<1961: C Granier ; N Ramankutty; JF Sousssana; B Dorim; Stern and Kaufmann, 1998 >1961: FAO	See table 4 +optimization
Geologic	Etiope and Klusman, 2002	See table 4; Etiope and Klusman, 2002
Termites		See table 4
Oceans		See table 4
Hydrates		See table 4

Global Carbon Project

Contemporary budget 1991-2006

Component	Historical reconstructions/ inventories	Inversions
Growth rate	Atmospheric data NOAA-ESRL	
Global OH	Model results (e.g., Prinn et al., 1995; Krol et al., 1998; Bousquet et al., 2005)	See table 4 +optimization
Global fires	Mouillot et al., 2006 (20th century), Chen and Prinn, 2006 (biomass burning); Stern and Kaufmann, 1998; Fung et al., 1991 (biomass burning)	See table 4 (+GFED, G Van der Werf +optimization)
Wetlands (drained?)	Matthews and Fung, 1987 & 1992; Ringeval et al., 2010; Chen and Prinn, 2006; EPA 1993; Kaplan 2002; Fung et al., 1991	See table 4 +optimization
Fossil	Marland et al., 2008	See table 4 +optimization
Coal mines/gas	Marland et al., 2008; Chen and Prinn, 2006; Stern and Kaufmann, 1998; Fung et al., 1991	See table 4 +optimization
Rice	<1961: C Granier; N Ramankutty; JF Soussana; B Dorim; Chen and Prinn, 2006; Stern and Kaufmann, 1998 >1961: FAO, EPA 1993; Fung et al., 1991	See table 4 +optimization
Livestock/ruminants	<1961: C Granier ; N Ramankutty; Soussana et al., 2007; B Dorim >1961: FAO; Fung et al., 1991	See table 4 +optimization
Geologic	Etiope and Klusman, 2002	See table 4; Etiope and Klusman, 2002
Termites	Chen and Prinn, 2006; Fung et al., 1991	See table 4 +optimization
Oceans		See table 4 +optimization
Hydrates	EPA 1993, Fung et al., 1991	See table 4 +optimization

Making the CH_4 global budget update more operational

- The recent anomaly:
  - What is the global magnitude?
  - What are the links to climate anomalies (El Niño/La Niña, ENSO)?
  - Which regions are important, which processes?

Component	Historical reconstructions/ inventories	Inversions
Growth rate	Atmospheric data NOAA-ESRL	Rigby et al., 2008
Global OH	Model results (e.g., Prinn et al., 1995; Krol et al., 1998; Bousquet et al., 2005)	See table 4 +optimization
Global fires	Mouillot et al., 2006 (20^{th} century), EPA 2010 (wildfires)	See table 4 (+GFED, G Van der Werf +optimization)
Wetlands (drained?)	B Ringeval; EPA 2010; Kaplan 2002; Wania 2010	See table 4 +optimization
Fossil	Marland et al., 2008	See table 4 +optimization
Coal mines/gas	Marland et al., 2008	See table 4 +optimization
Rice	<1961: C Granier; N Ramankutty; JF Soussana; B Dorim >1961: FAO; EPA 2010	See table 4 +optimization
Livestock/ruminants	<1961: C Granier; N Ramankutty; JF Soussana; B Dorim >1961: FAO; EPA 2010	See table 4 +optimization
Geologic	Etiope and Klusman, 2002; EPA 2010	See table 4; Etiope and Klusman, 2002
Termites	EPA 2010	See table 4 +optimization
Oceans	EPA 2010	See table 4 +optimization
Hydrates	Shakova et al., 2010	See table 4 +optimization

Contemporary budget 2007-ongoing

Making the CH_4 global budget update more operational

- Activity 2:
  - Produce annual update of CH_4 inversion fluxes/provide global top-down estimates of CH_4 emissions
  - Global inversion fluxes
  - Global error
  - At what scales and time resolution? How to gather atmospheric data? Prior info? Models?

Making the CH_4 global budget update more operational

- Activity 3:
  - Provide a product of estimated CH_4 fields/optimized atmosphere → possibility for forward modeling efforts
  - Extract model data for station locations and provide to experimental groups for feedbacks

Emission Inventories

- EDGAR v4.0: mostly anthropogenic sources/CH_4 emissions
- Matthews & Fung: wetlands + rice, natural sources
- J Kaplan: wetlands, global and regional estimates of natural CH_4 sources
- Vegetation models (e.g., ORCHIDEE, LPJ-WHyMe, …): wetland emissions
- FAO: agricultural sources (rice, ruminants)
- GFED3.1: biomass burning
- S. Houweling/Lambert: ocean emissions
- S. Houweling/Lambert: wild animals
- Sanderson: termites
- Ridgewell: soil sink

References	Indicative ^{13}C, ‰	Hein et al., 1997	Houweling et al., 2000	Olivier et al., 2005	Wuebbles and Hayhoe, 2002	Scheehle et al., 2002	J. Wang et al., 2004	Mikaloff Fletcher et al., 2004	Chen and Prinn, 2006	Bousquet et al., 2010	TAR	AR4
Base year		1983-1989		2000		1990	1994	1999	1996-2001	1984-2008	1998	2000-2004
Natural sources			**222**		**145**		**200**	**260**	**168**	**208**		
Wetlands	-58	231	163		100		176	231	145	170		
Termites	-70		20		20		20	29	23	21		
Ocean	-60		15		4					18		
Hydrates	-60				5		4					
Geological sources	-40		4		14							
Wild animals	-60		15									
Wildfires	-25		5		2							
Anthropogenic sources		**361**		**320**	**358**	**264**	**307**	**350**	**428**	**334**		
Energy						74	77					
Coal mining	-37	32		34	46			30	48			
Gas, oil, industry	-44	68		64	60			52	36	58		
Landfills and waste	-55	43		66	61	69	49	35		58		
Ruminants	-60	92		80	81	76	83	91	189	85		
Rice agriculture	-63	83		39	60	31	57	54	112	36		
Biomass burning	-25	43			50	14	41	88	43	35		
C3 vegetation	-25			27								
C4 vegetation	-12			9								
Total sources		**592**			**503**		**507**	**610**	**596**	**542**	**598**	**582**
Imbalance		+33									+22	+1
Sinks												
Soils	-18	26			30		34	30		25	30	30
Tropospheric OH	-3.9	488			445		428	507			506	511
Stratospheric loss		45			40		30	40			40	40
Total sink		**559**			**515**		**492**	**577**			**576**	**581**

Modeling: Challenges

- Exchange with data PI's has to be formulated
- Difficulties assessing OH fluctuations
- Absolute value for CH_4 is difficult to assess because of OH uncertainties
- Alternative for methyl chloroform is needed → other CFC's, ^{14}CO (Krol et al., 2008)

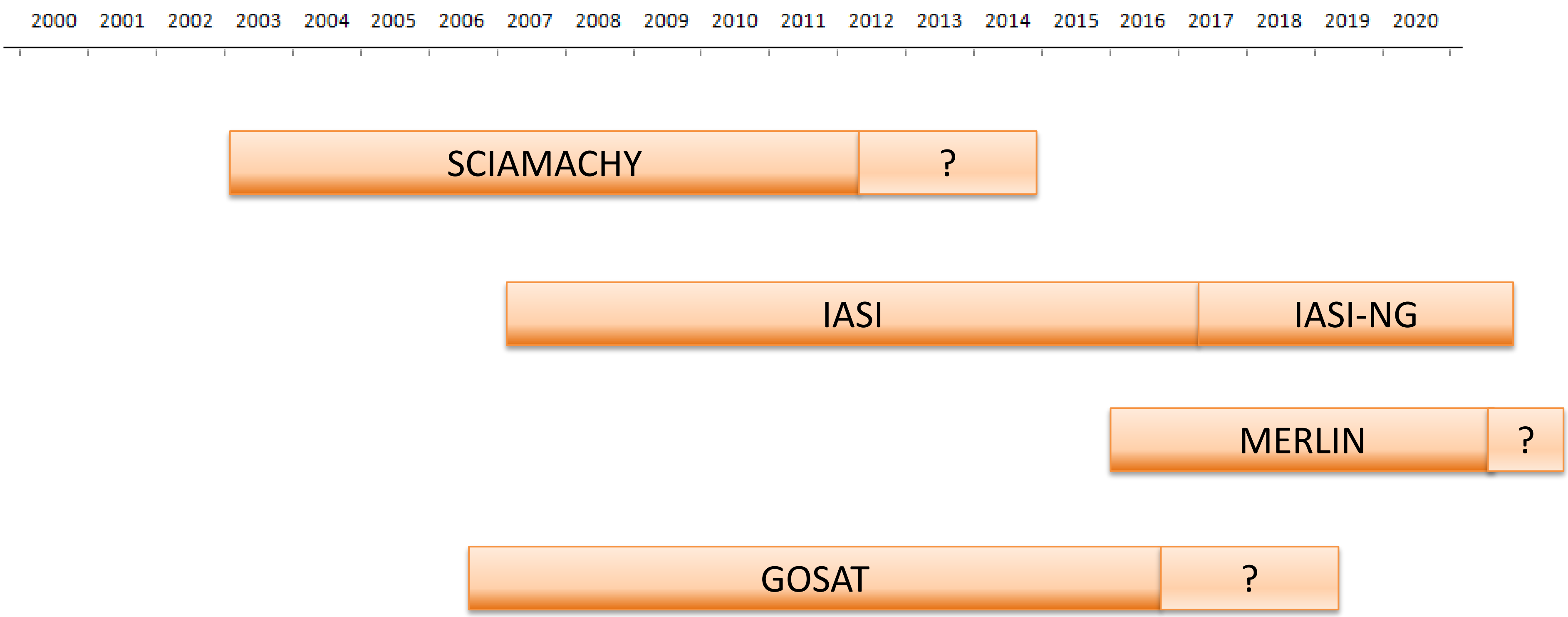
Observations: Challenges

- Continuous and air flask measurements
- NOAA, CSIRO, WMO-GAW, ICOS
- Need for long-term, in situ measurement program with high analytical standards
- Sustain continuity and quality
- Large gaps – need for tropical data, isotope measurements

Aircraft data

- NOAA aircraft profiles
- NOAA/IPEN aircraft profiles
- CSIRO air sampling network?
- LSCE air sampling network on GEOmon airborne data archive
- CARIBIC?
- MaMap?

Satellite data



Discussion…