Role of atmospheric dynamics on interannual variability in methane concentration

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Non-CO_2 Greenhouse Gases (NCGG-5)

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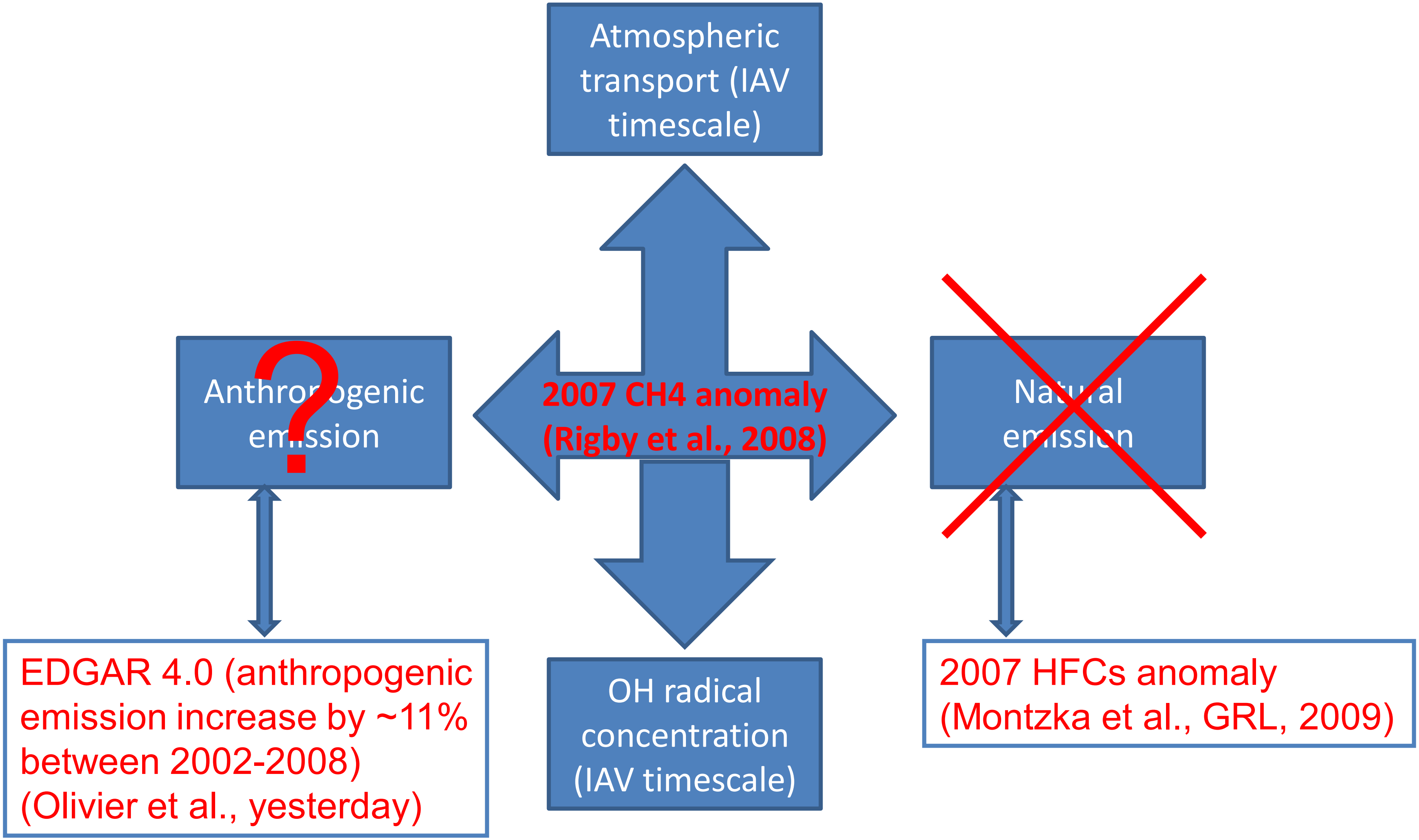
Rationale


Atmospheric transport (IAV timescale)
Anthropogenic emission
?
2007 CH4 anomaly
(Rigby et al., 2008)
Natural emission
OH radical concentration (IAV timescale)
EDGAR 4.0 (anthropogenic emission increase by ~11% between 2002-2008) (Olivier et al., yesterday)
2007 HFCs anomaly (Montzka et al., GRL, 2009)

Framework for online CH_4 simulation

- CCSR/NIES/FRCGC AGCM-based CTM (**ACTM**) run at resolution T42 L67 (top 90km)
- NCEP-2 reanalysis meteorology (U,V,T nudged)
- Hadley Center Sea-Surface Temperature & Sea-Ice Cover
- CH_4 chemistry (Sander et al., JPL Pub. 06-2, 2006) as:

$CH_4 + O^1D \rightarrow$ Products ($K_{O^1D} = 1.5 \times 10^{-10}$)

$CH_4 + OH \rightarrow CH_3 + H_2O$ ($K_{OH} = 2.45 \times 10^{-12} \exp(-1775/T)$)

$CH_4 + Cl \rightarrow CH_3 + HCl$ ($K_{Cl} = 7.3 \times 10^{-12} \exp(-1280/T)$)

$CH_4 + h\upsilon \rightarrow$ Products (wavelength dependent; not considered here)

- All the radicals are taken from CHASER/STRAT (Sudo et al., Takigawa et al.) models at monthly (or hourly) intervals

Surface flux types and annual budget of CH_4

ACTM: EDGAR3.2 anthropogenic; GISS natural/biogenic

Sources	Range Estim. Reported by IPCC [2001]	A Priori Estimates, Tg CH_4/yr
Total wetlands	92-237	
Swamps		91[c]
Bogs and tundra		54[c]
Rice agriculture	25-100	60[d]
Ruminant animals	80-115	93[d]
Termites	20-20	20[e]
Biomass burning	23-55	52[f]
Energy	75-109	
Coal		38[d]
Natural gas and other industrial		57[d]
Landfills	35-73	50[g]
Ocean	10-15	10[h]
Hydrates	5-10	5[h]
Total source	**500-600**	**530**

Sinks		A Priori Estimates, Tg CH_4/yr
Tropospheric OH	450-510	507[i]
Stratospheric loss	40-46	40[k]
Soils	10-30	30[k]
Total		**577**

Year	Total emission (E2)
1988	569.4
1989	570.6
1990	571.1
1991	571.7
1992	572.3
1993	572.9
1994	573.4
1995	574.0
1996	574.3
1997	574.7
1998	574.1
1999	574.5
2000	575.0
2001	574.7
2002	574.2
2003	574.9
2004	574.6
2005	574.8
2006	574.8

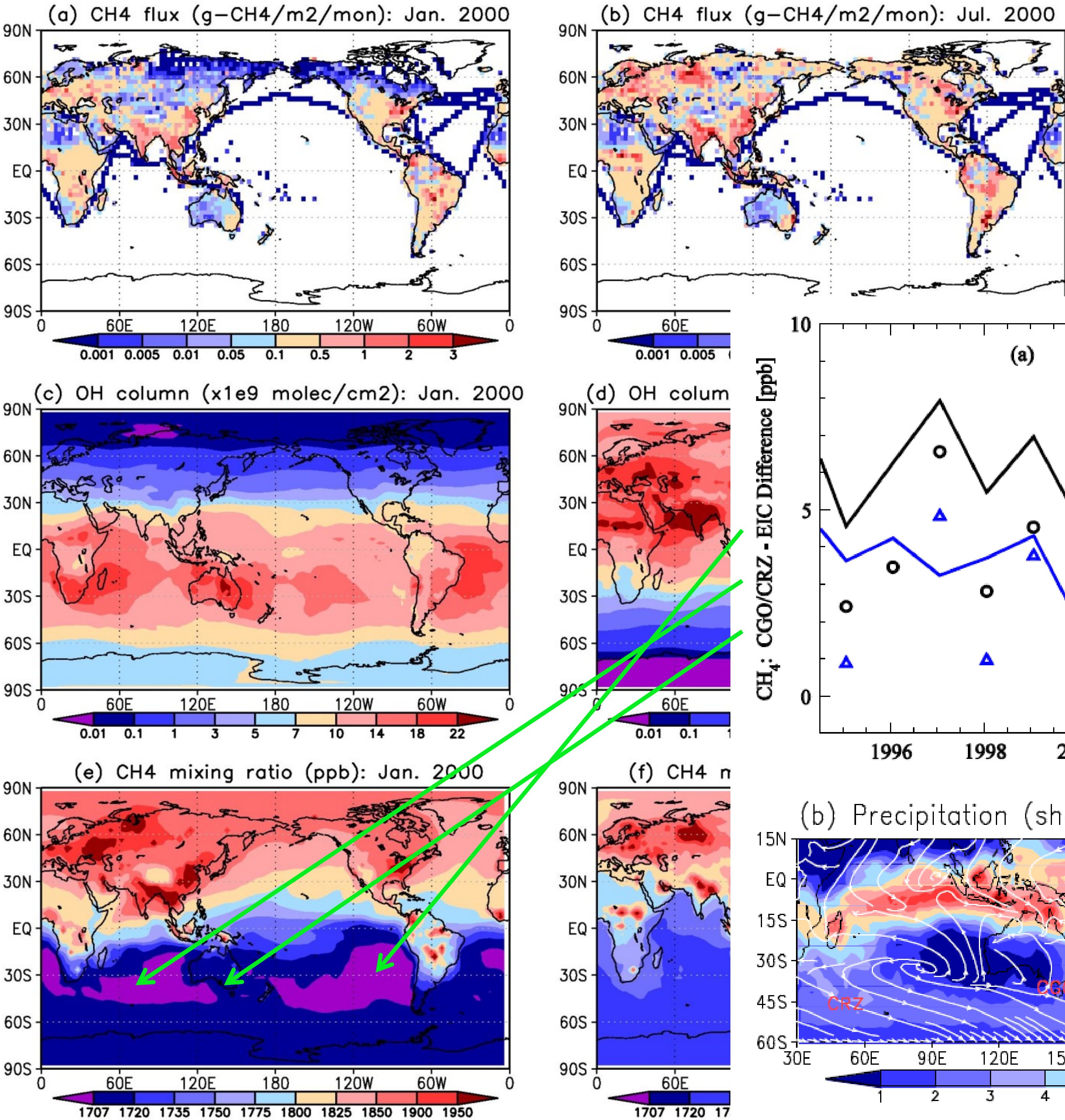
Tropospheric Budget (E2)	Year 2000 (E2)
Anthropogenic*	**301.9**
Biofuel	16.0
Fossil fuel	102.9
Industrial	0.9
Animal + Fire	119.3
Waste	62.7
Biogenic**	**273.0**
Termites	20.5
Biomass Burn	59.8
Rice	39.4
Swamps	104.4
Bogs	40.2
Tundra	8.7
Sinks	**~580**
Trop. Loss	551
Strat. Loss	29
NH Loss	334
SH Loss	246
Atmos. Burden	**4999**

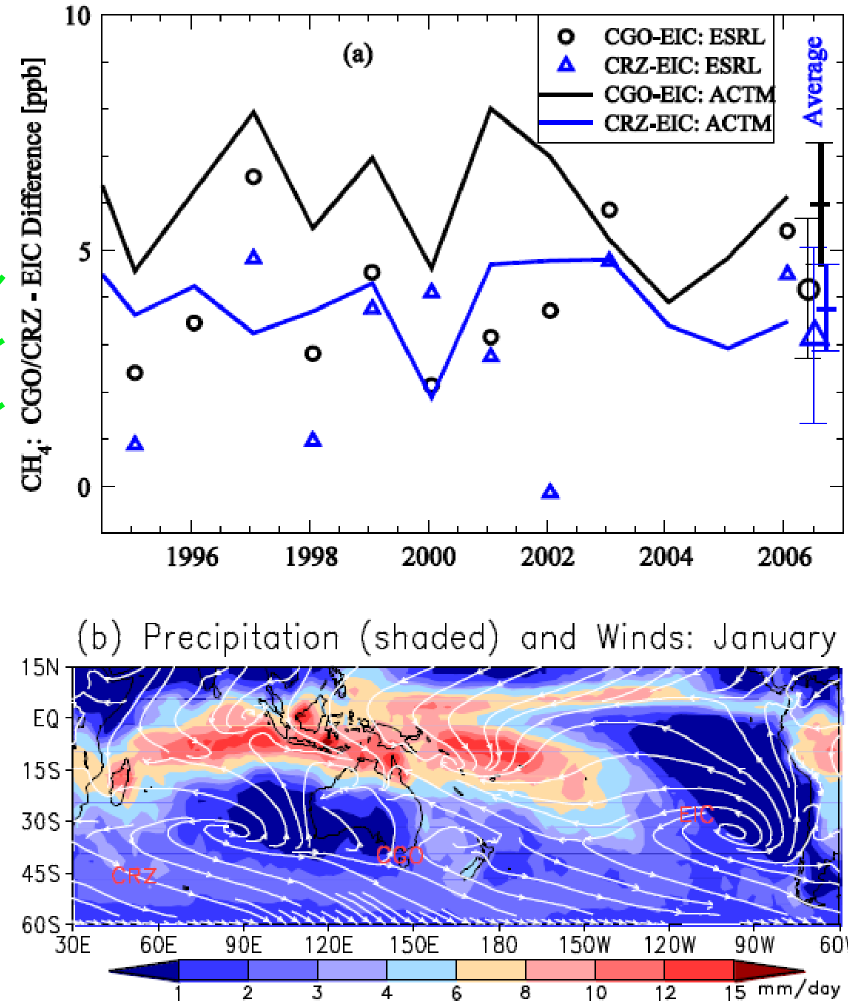
Top emission country(E2)	Aggr. Emission (E2)
Brazil	54.2
USA	54.0
Russia	51.3
China	47.4
India	41.1
Indonesia	30.1
Canada	17.3
Argentina	14.9
Australia	11.7
Thailand	10.7
Zaire	8.9
Nigeria	8.7
Sudan	8.6
Mexico	8.1
Venezuela	7.1
Ukraine	6.6
Vietnam	6.5
Pakistan	6.4
Peru	6.3

Mikaloff Fletcher et al., GBC, 2004

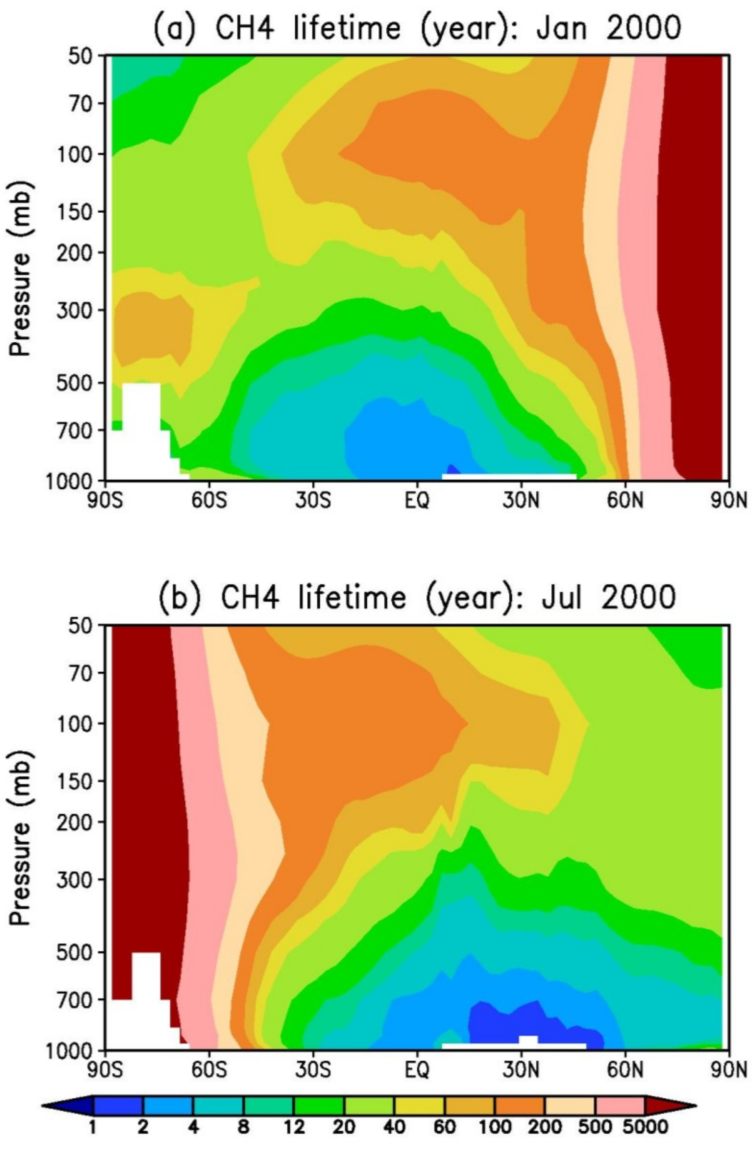
Patra et al., JMSJ, 2009

CH_4 emission, sinks, and concentration





CH_4 lifetime and budgets



Instantaneous CH_4 Lifetime

$$= 1/[K_{OH}\cdot OH + K_{O^1D}\cdot O^1D + K_{Cl}\cdot Cl]$$

(useful for understanding the dominance of dynamics vs. chemistry on variability)

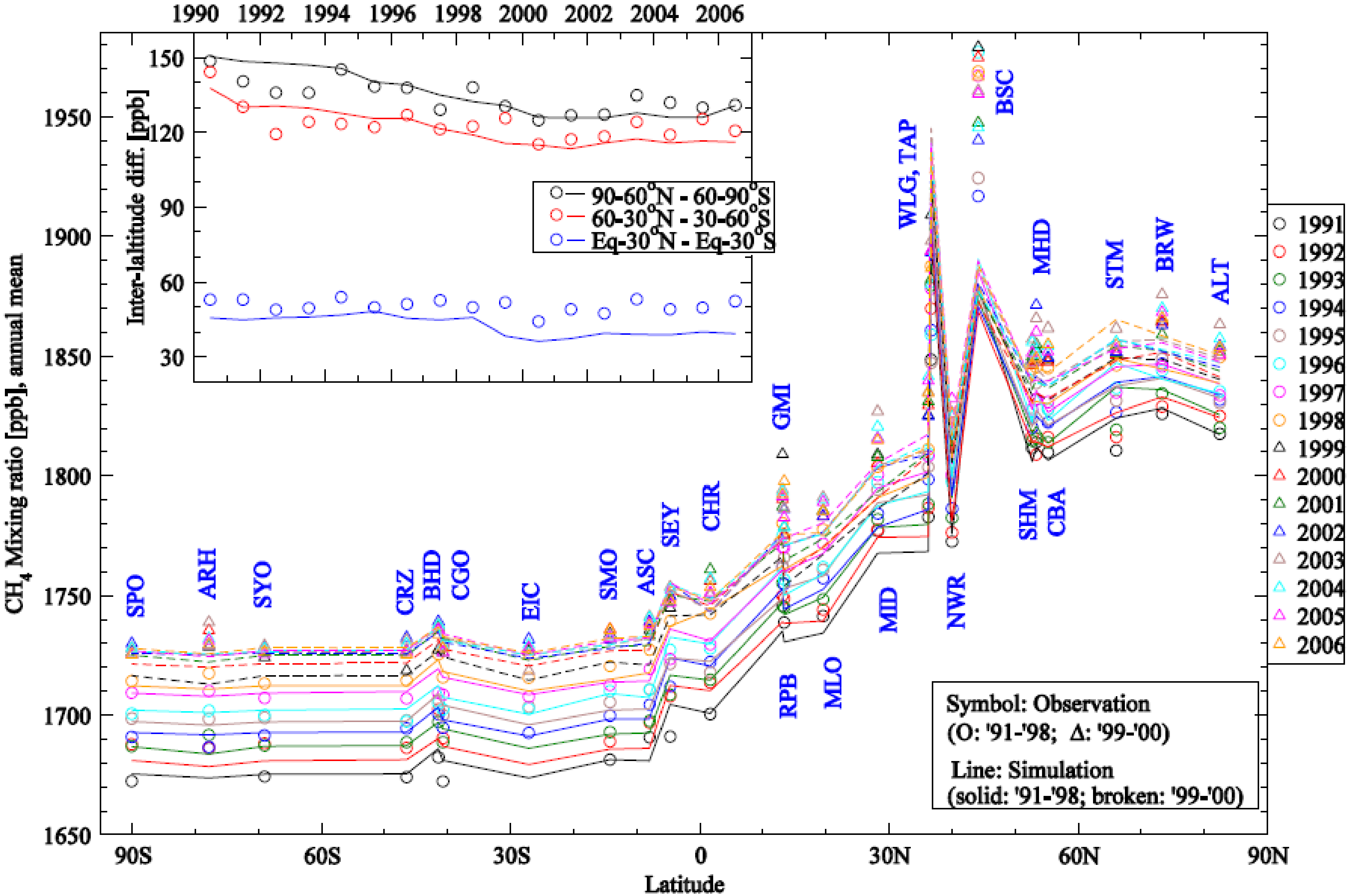
Atmospheric Lifetime = burden/loss

(Prather et al., IPCC, 2001)

CH_4 L. T. = 4999 Tg/580 Tg yr^{-1} = 8.62 years

Estimates	Atmospheric Lifetime	References
IPCC TAR	8.4	Prather et al.
IPCC FAR (prescribed)	8.67±1.32(m#26) 8.45±0.38 (m#12)	Stevenson et al., JGR, 2006
This work (full model)	8.62	Patra et al., JMSJ, 2009

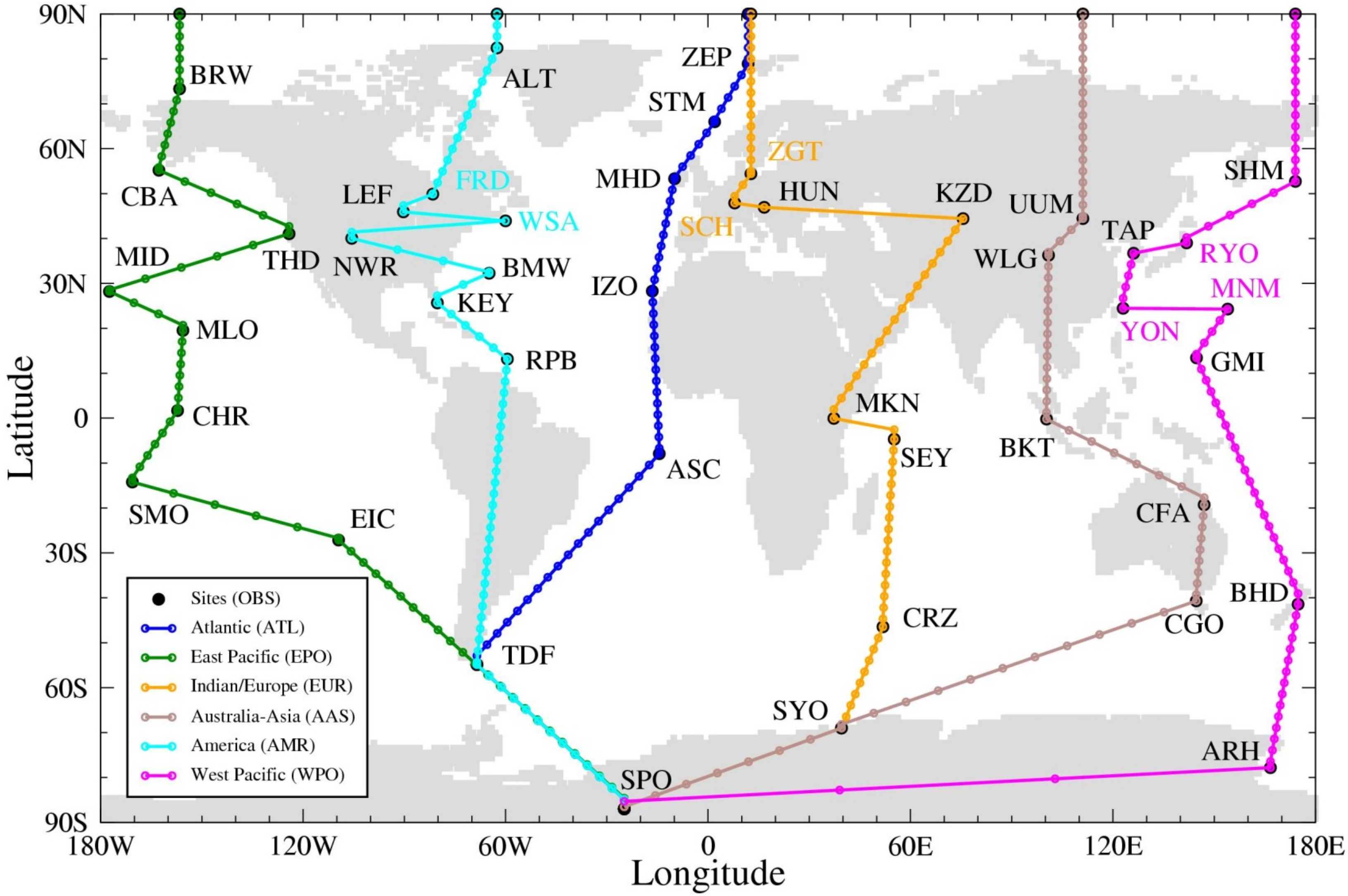
CH_4 latitudinal gradients



Patra et al., JMSJ, 2009

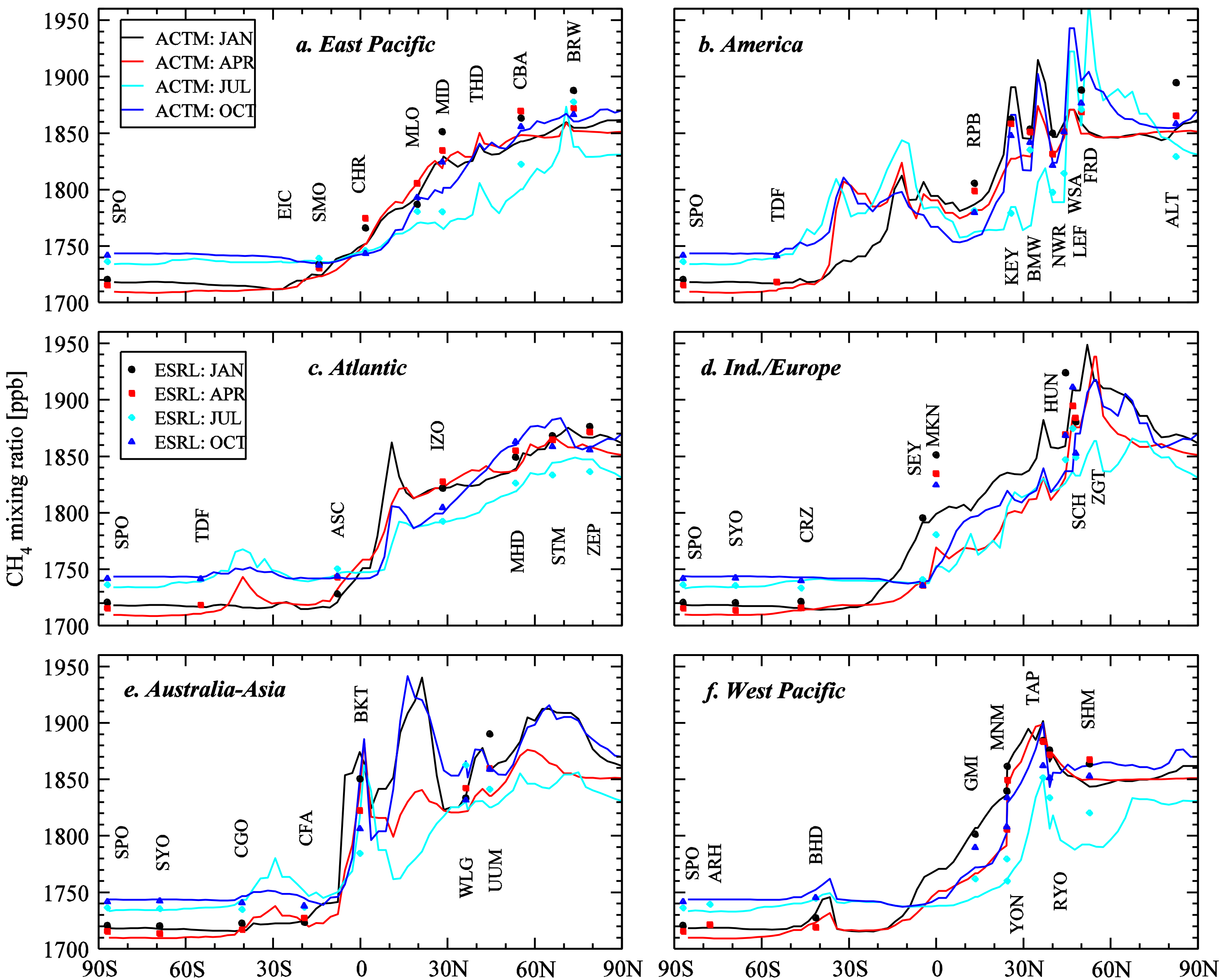
CH_4 Measurement Sites – can we track emissions?

(~50 used here; >100s are in operation in 2007)



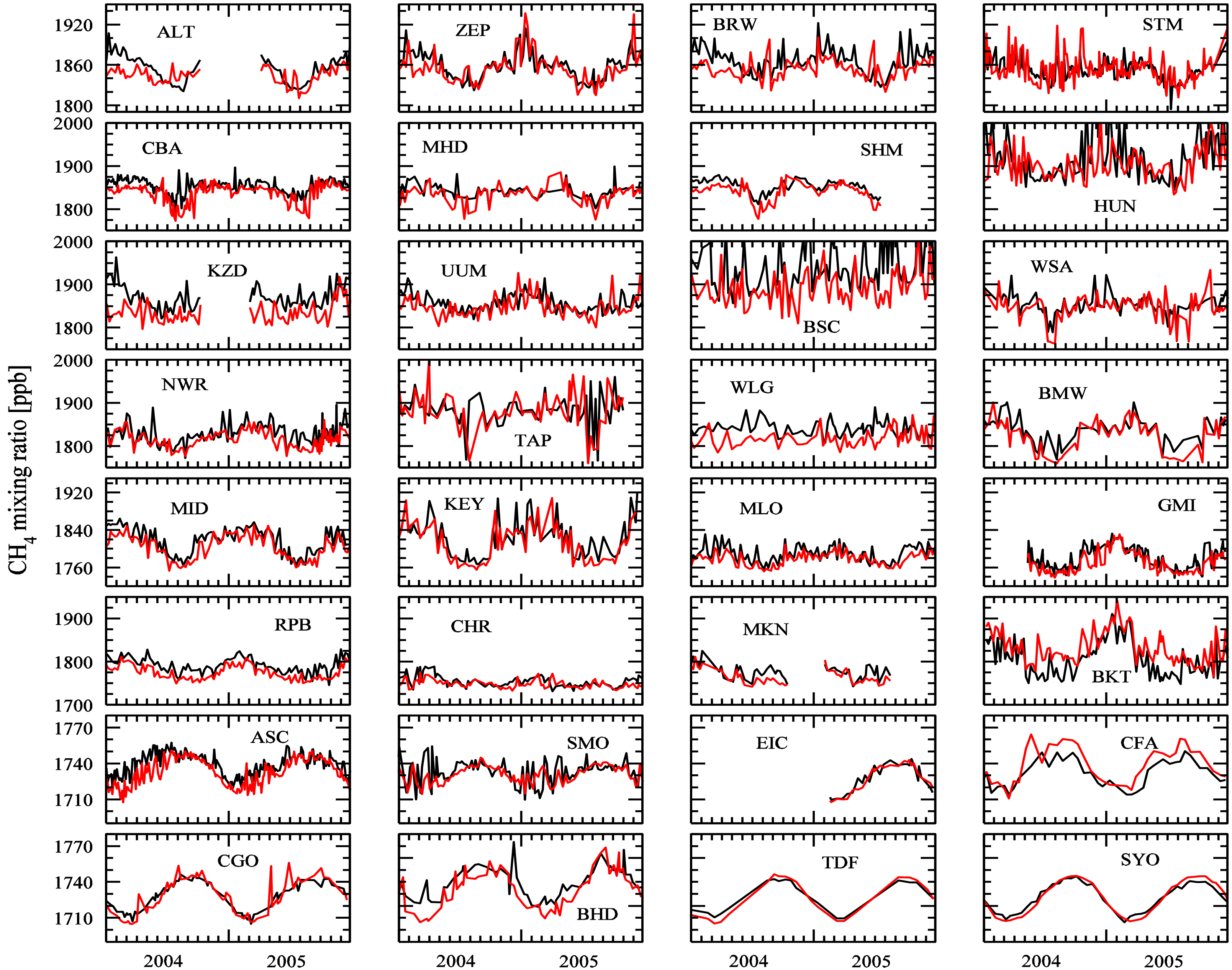
<u>Contributing Institutes:</u> 1. NOAA/ESRL, 2. FEA, Germany, 3. JMA, Japan, 4. EC, Canada, 5. NIWA

CH_4 latitudinal gradients: seasonal and longitudinal variations



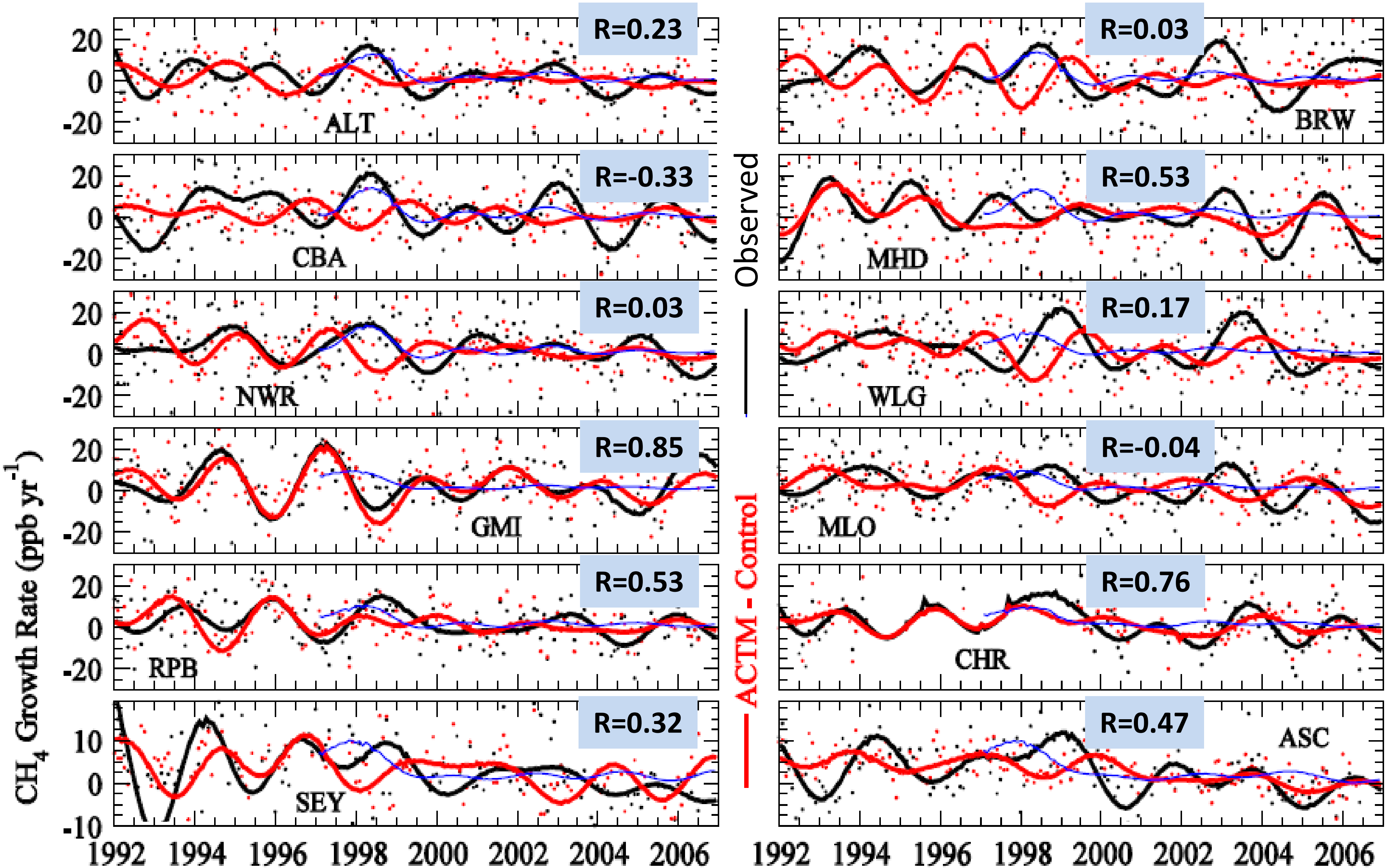
Patra et al., US EPA proc., April 2009

CH_4 seasonal cycles: Model-Observation comparison



Patra et al., JMSJ, 2009

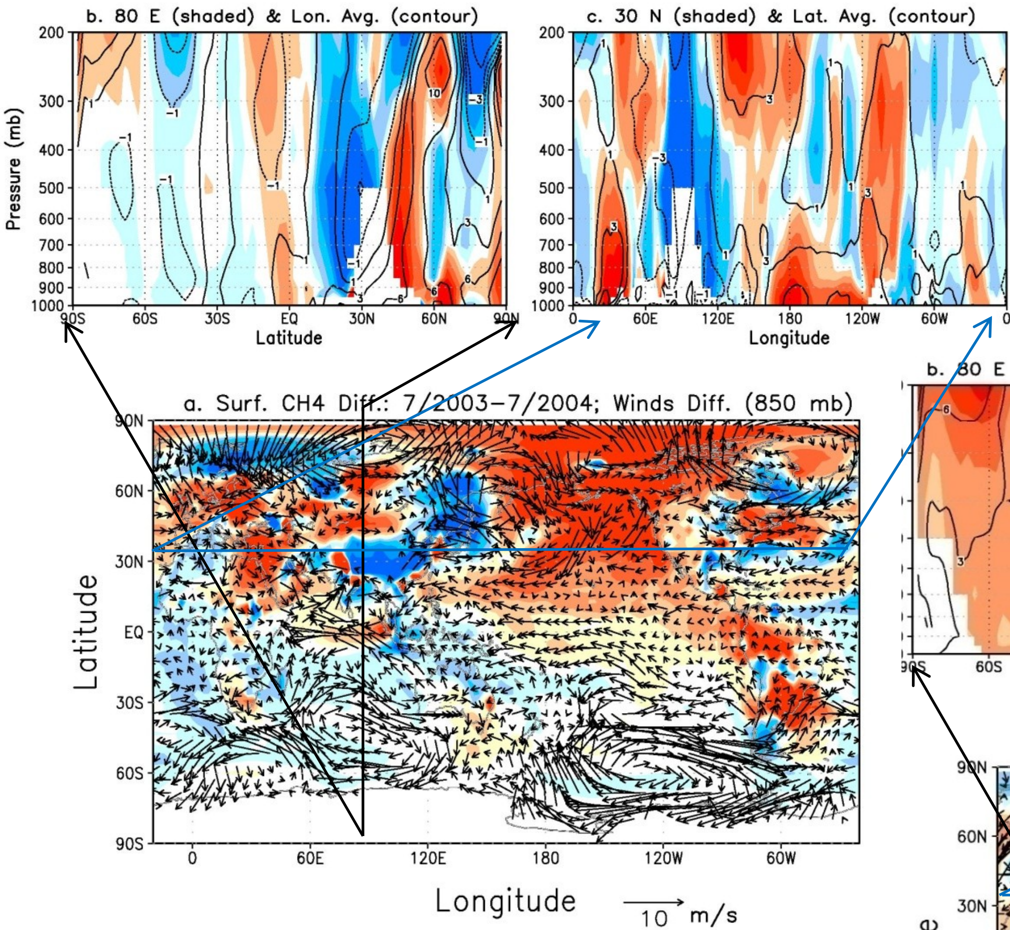
CH_4 growth rate IAVs: Transport domination in tropics and SH



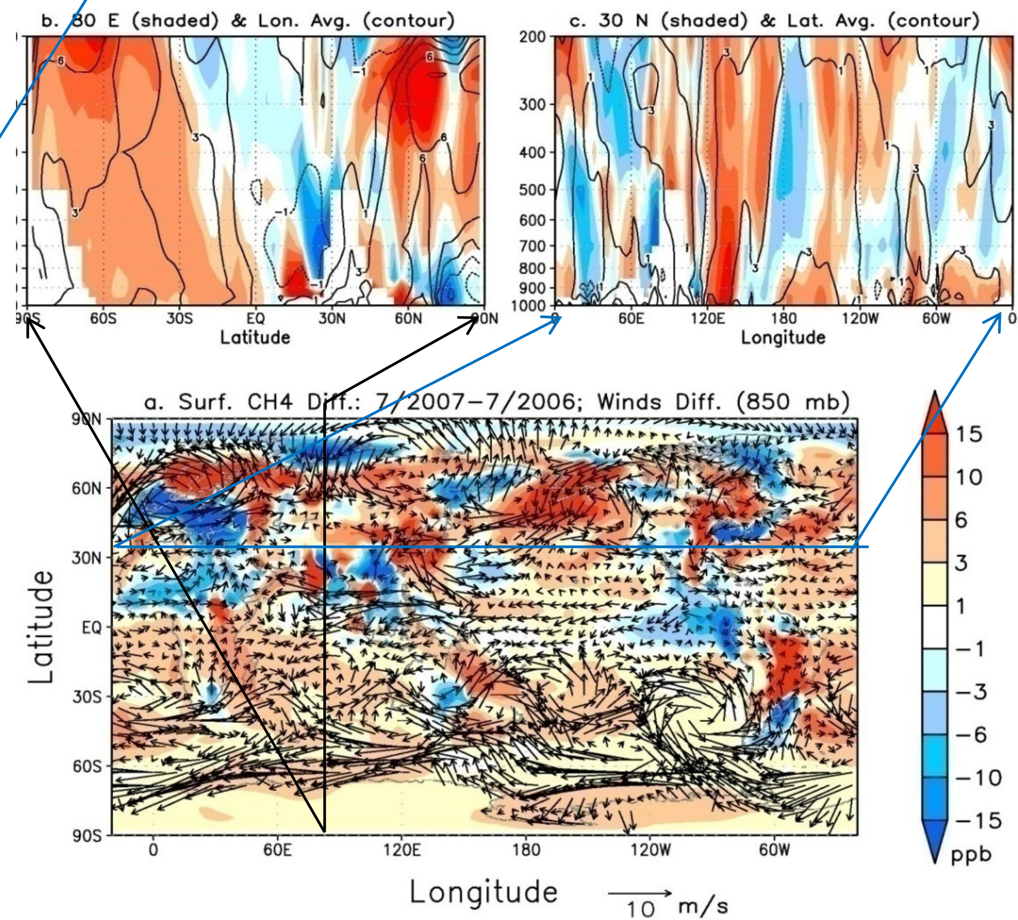
R = 0.69 (SMO), 0.66 (CGO), 0.35 (BHD), 0.46 (SYO), 0.42 (SPO) at SH sites

CH_4 growth rate IAV (July) – dynamical control

2004-2003

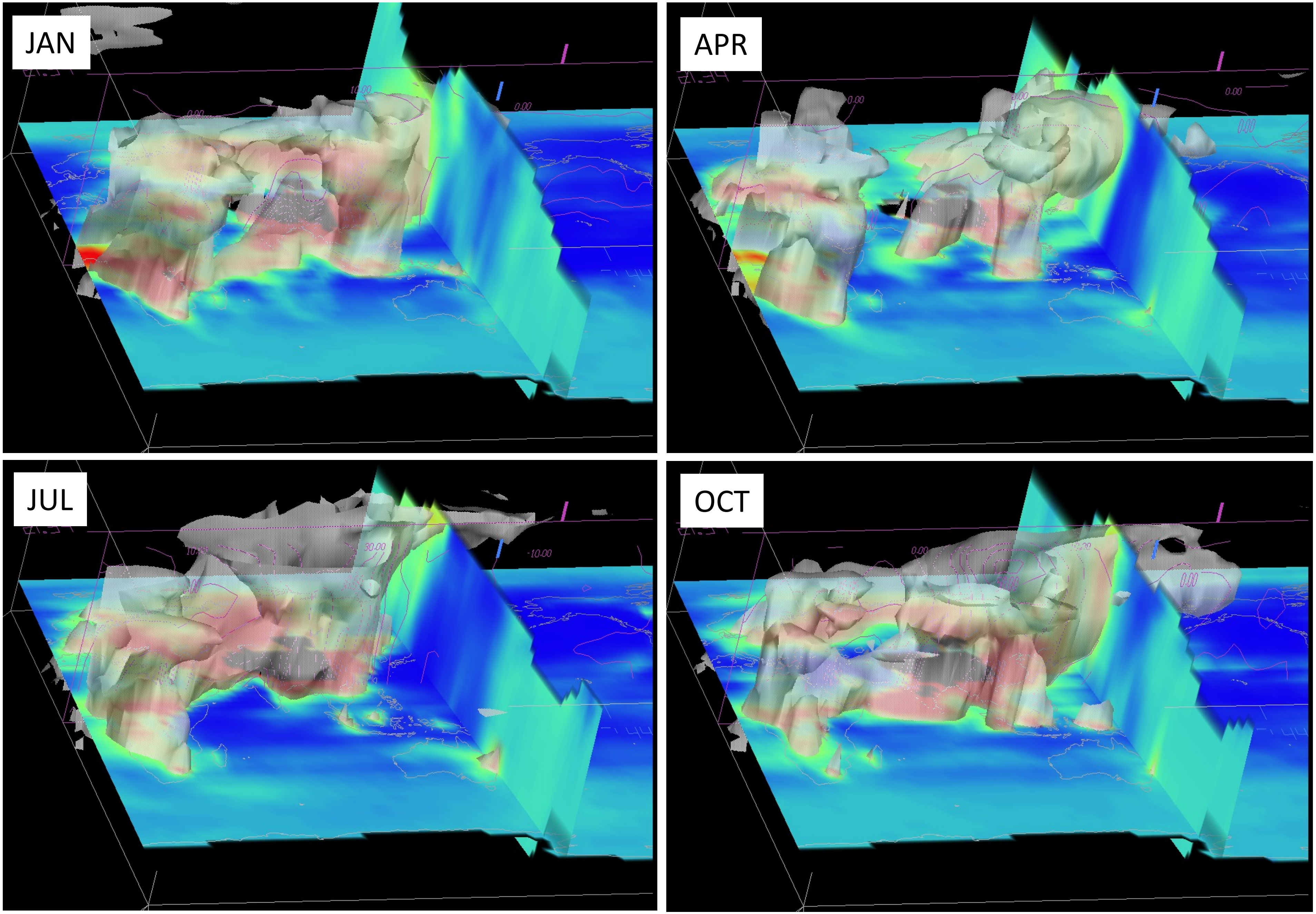


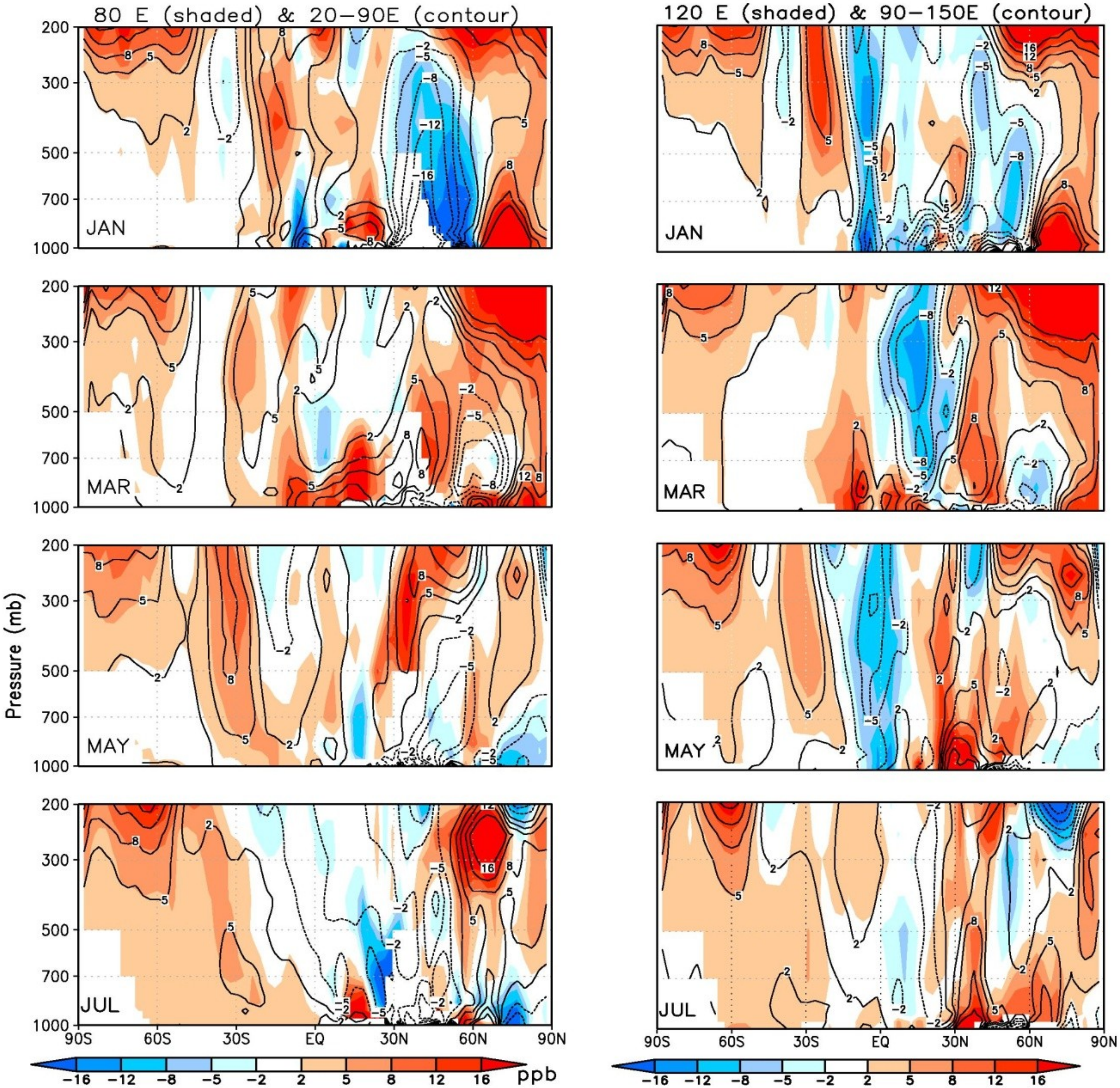
2007-2006



Patra et al., JMSJ, 2009

The +10ppv isosurface and crosssections of longitudinal CH_4 anomaly





Temporal evolution of the 2007 CH_4 high positive growth rate anomaly (2007-2006)

Left col.: over Africa

Right col.: over Asia

Conclusions

- ACTM CH_4 simulations have been optimised for a combinations of Fluxes, Radicals and Transport
  - Model-observation comparisons have been satisfactory for
    - IHG & IHG seasonal cycles
    - Seasonal cycles
    - Synoptic variations
    - Diurnal cycles
  - large part of the IAVs in CH_4 (as well as others) concentration are likely to arise from atmospheric transport IAV
  - Based on EDGAR 4.0 role of anthropogenic emission on 2007 CH_4 anomaly should be explored

Acknowledgements

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