Variabilities in greenhouse gases over (South) Asia due to monsoon

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JAMSTEC

Introduction

- Asia is one of the most intense source region of greenhouse gas emission
  - CO_2: China, India, Japan are 1st, 3rd and 5th largest emitters (EDGAR/CDIAC/IEA)
  - CH_4: about 40% of 535 Tg-CH_4/yr is emitted from Asia (Patra et al., 2016)
  - Also a major source of N_2O (N in general) due to nitrogen fertilizer use (Thompson et al., 2014; Saikawa et al., 2014)
- Long-lived tracers provide a different perspective of the transport pathways
- It is important to understand the source-receptor relationships before inverse modelling of regional sources and sinks

Atmospheric Chemistry-Transport Model (ACTM): understanding and improving fundamentals

$$\frac{dCH_4(x,y,z,t)}{dt} = S_{CH4}(x,y,t) - L_{CH4}(x,y,z,t) - \nabla \cdot \mathrm{F}_{CH4}(x,y,z,t)$$

where,

CH_4 = concentration in the atmosphere

S = Source/emission of constituent

L = Loss/sink of constituent (mainly by OH reaction)

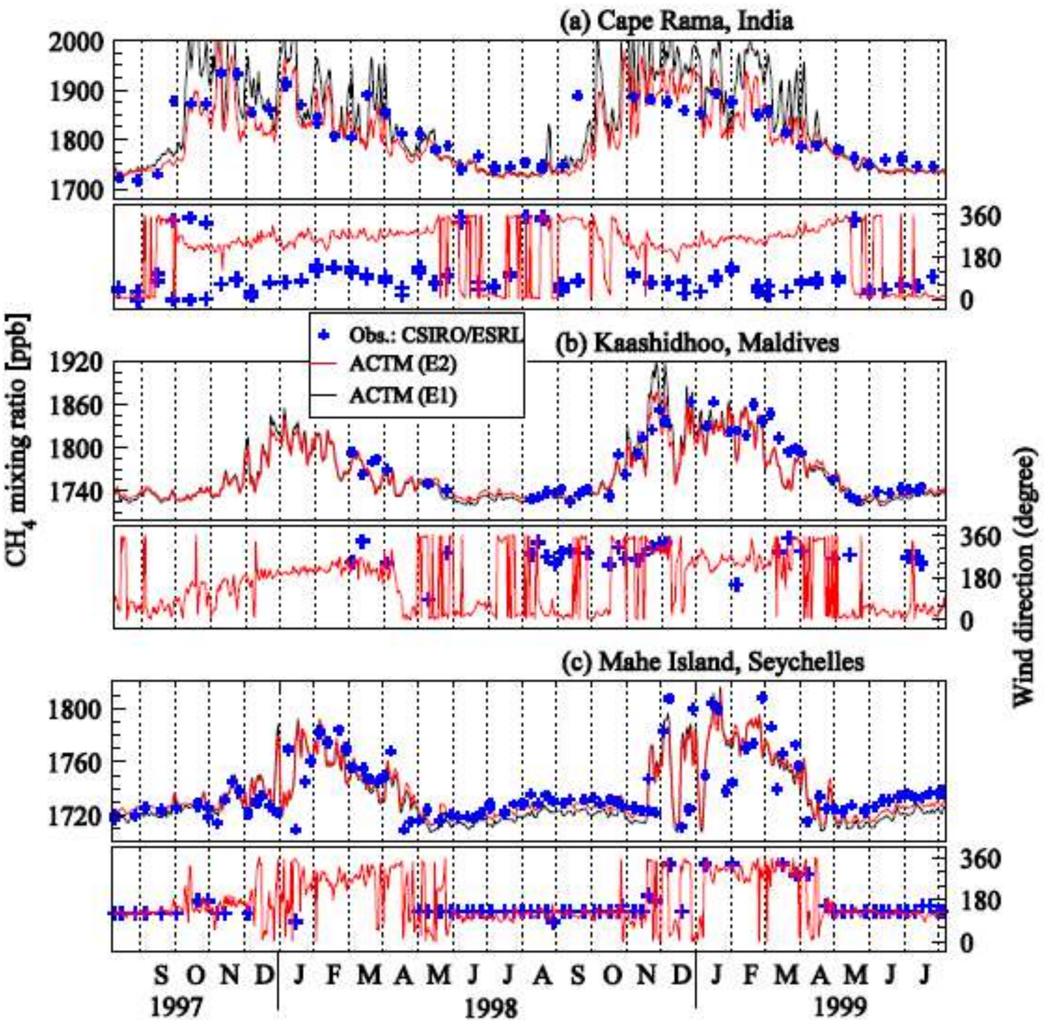
$\nabla \cdot \mathrm{F}$ = transport by diffusion, advection and convection

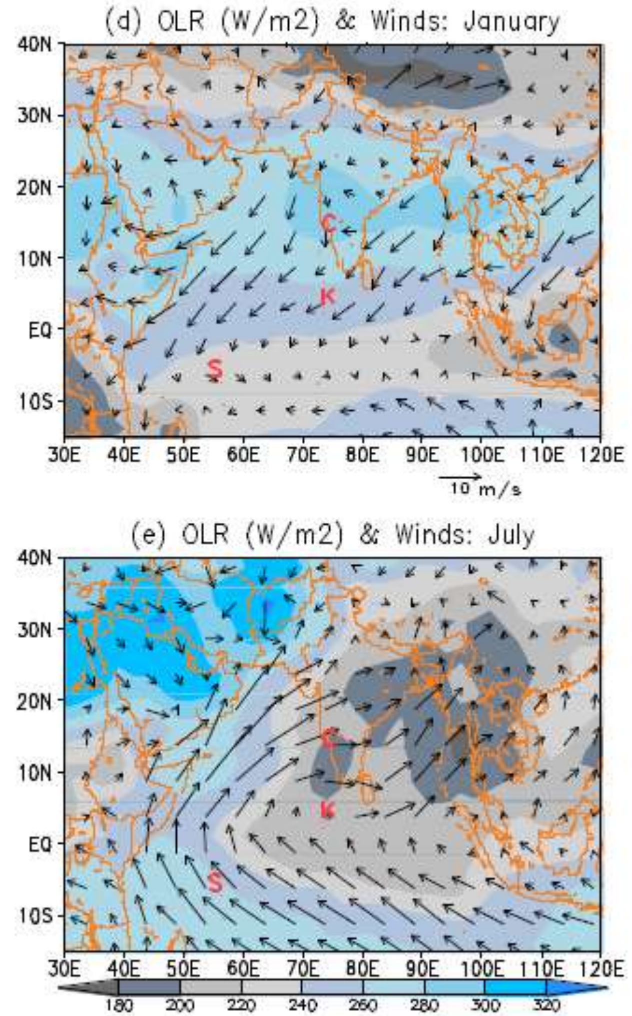
Species	Timescales/Lifetimes		
	Source	Loss~	Transp.
CO_2	~Hour	100 yr	PBL/Dly
CH_4	~Day	10 yr	Hem./Mn
N_2O	~Day	120 yr	IH/Yr
SF_6	~Year	>3000	IH/Yr

We use JAMSTEC's **ACTM** in this study (transport is driven by the CCSR/NIES/FRCGC AGCM v5.7b, nudged with JMA reanalysis – JRA55)

We **characterised OH** for the global mean concentration (the main 'Loss' term) and NH/SH ratio (Patra et al., Nature, 2014)

CH_4 Seasonal Cycles at Surface – produced by chemical loss and South Asian monsoon

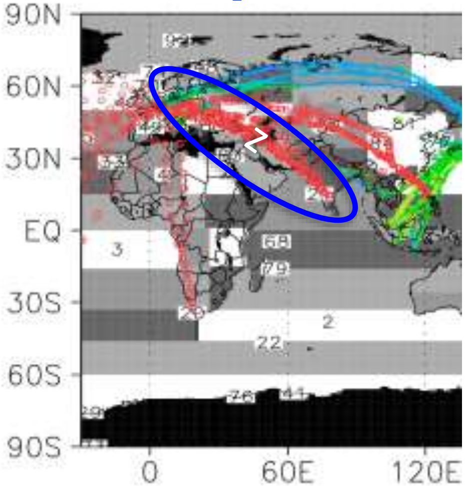


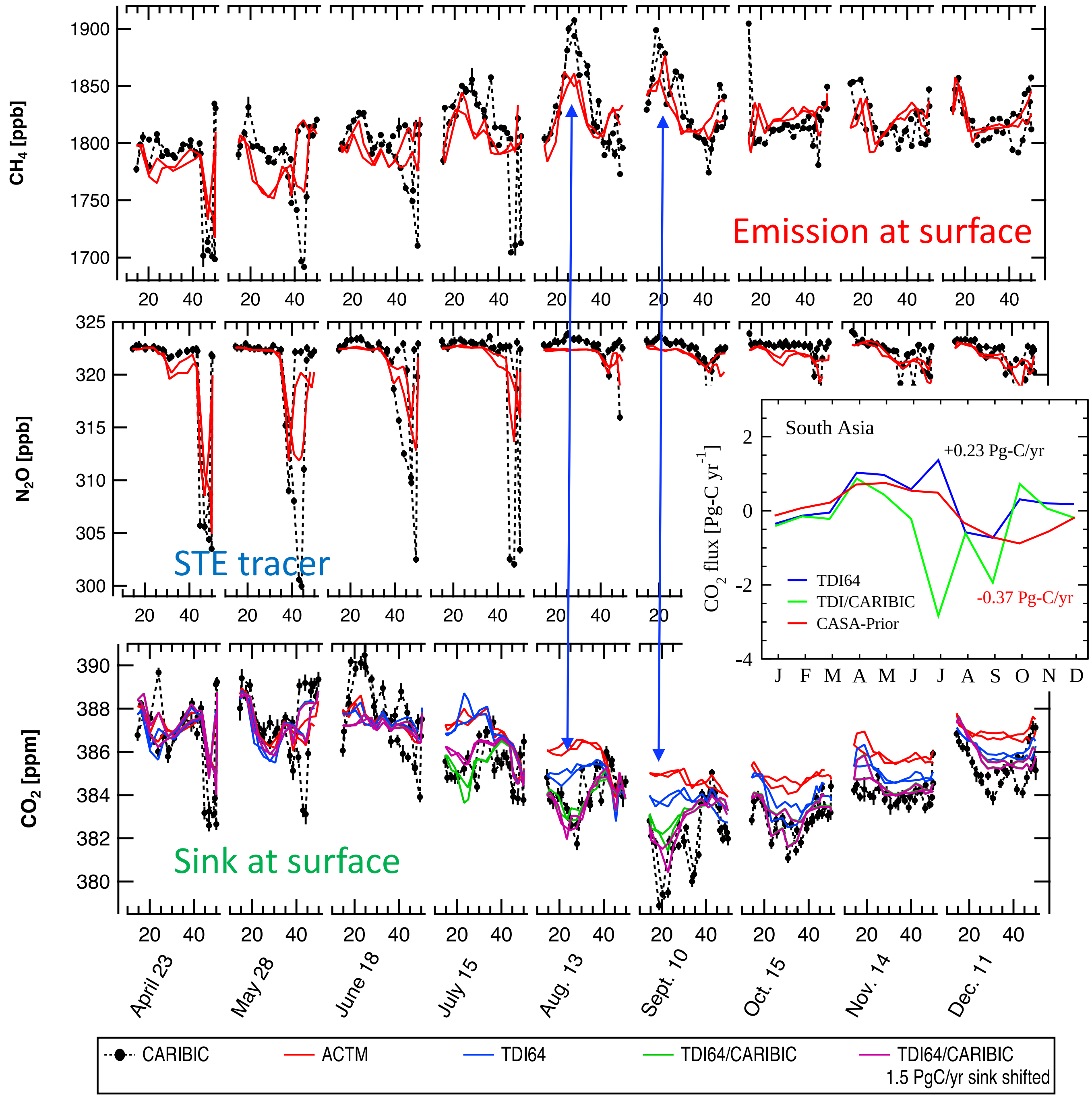


Patra et al., JMSJ, 2009

CH_4, N_2O, CO_2 Variability over India, between Chennai-Frankfurt

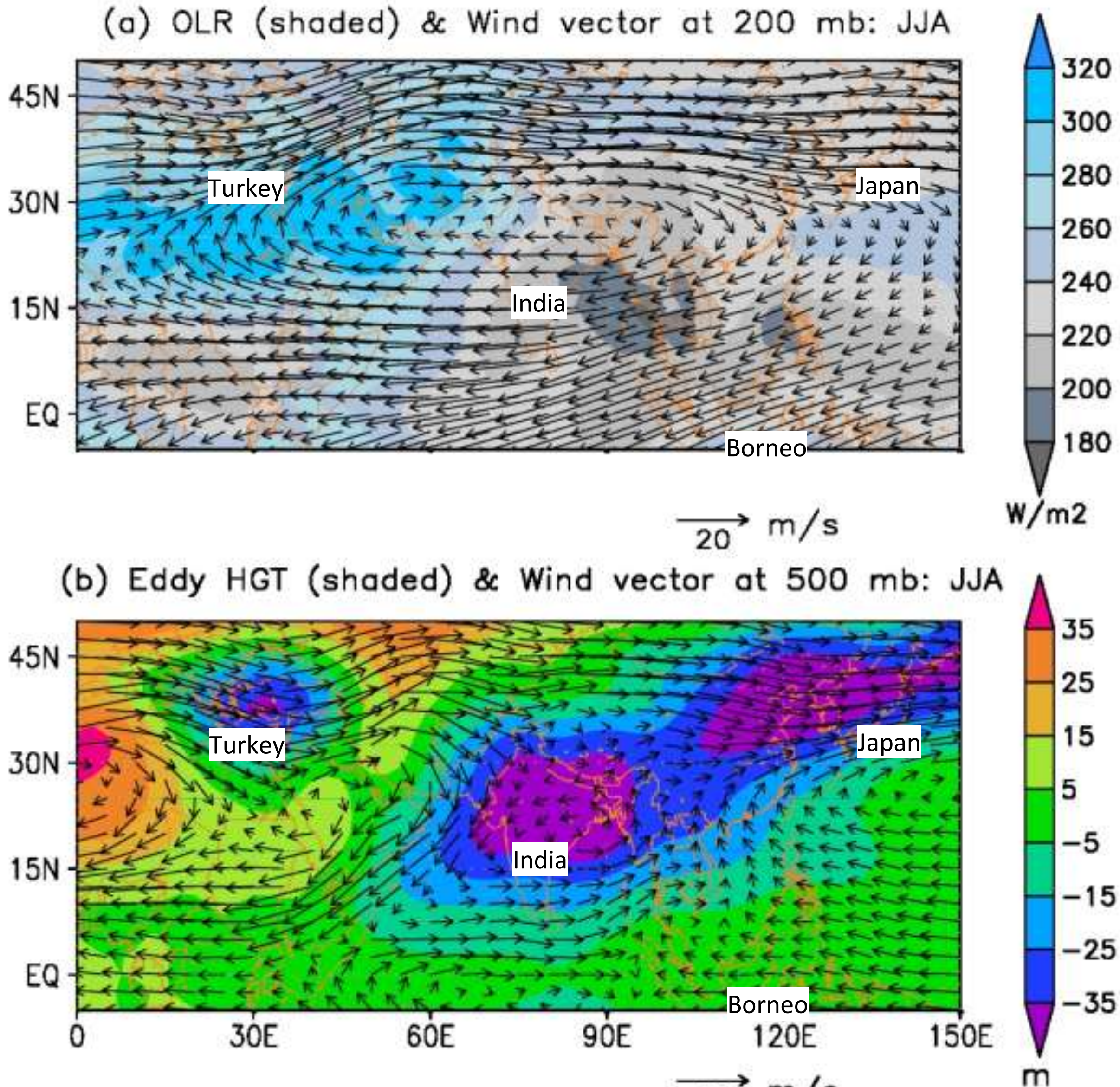
CARIBIC CO_2 data for 2008





Patra et al., ACP, 2011

Dynamical conditions: South to East Asian transport corridor



Clear sky /
High pressure

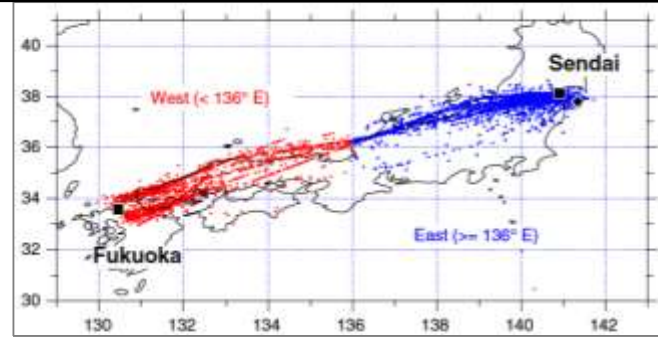
Cloudy sky /
low pressure

Downwelling motion

Upwelling motion

See also:
Xiong et al., 2009
Park et al., 2007

Transport of CH_4 emission signal from India to Japan



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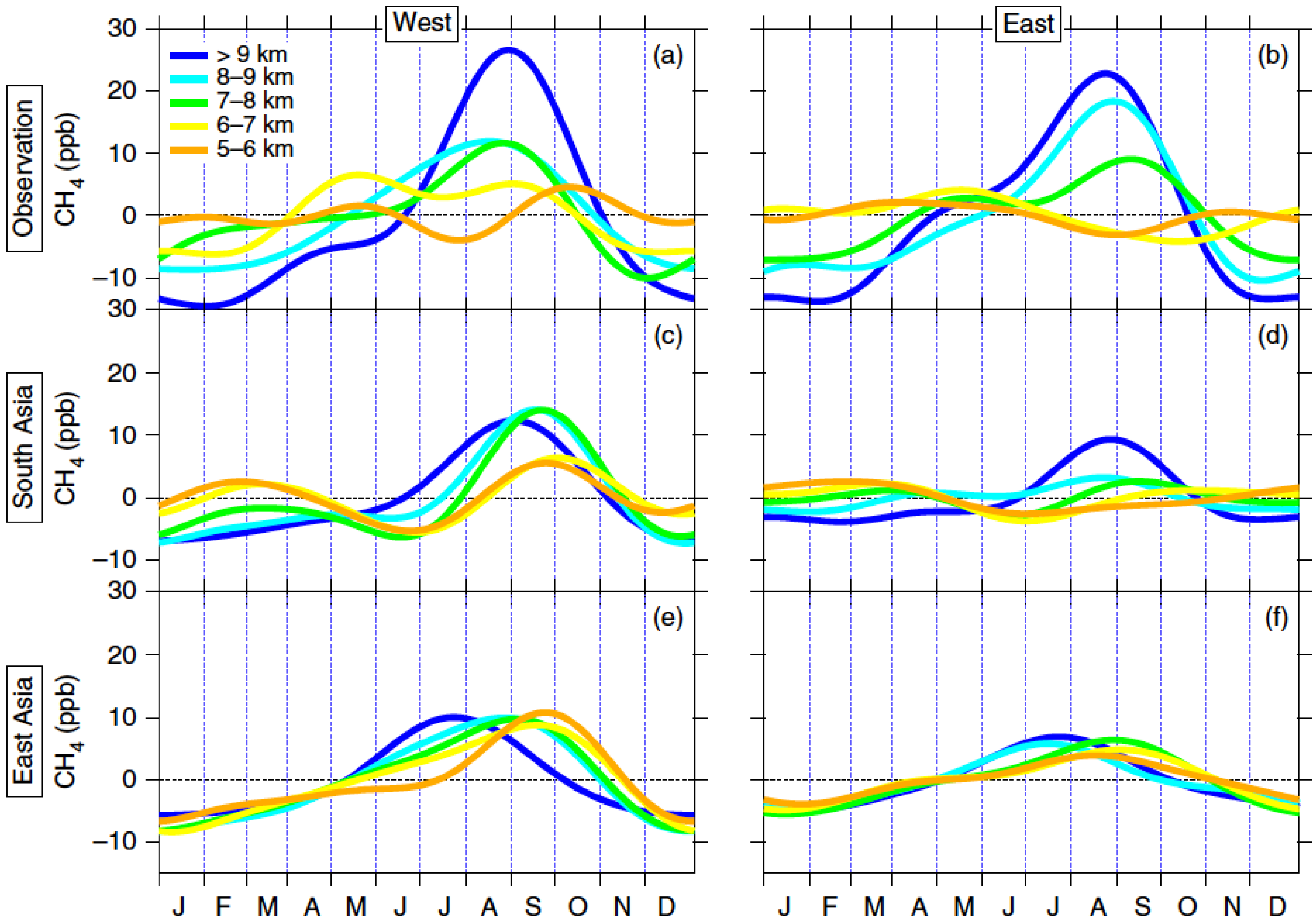
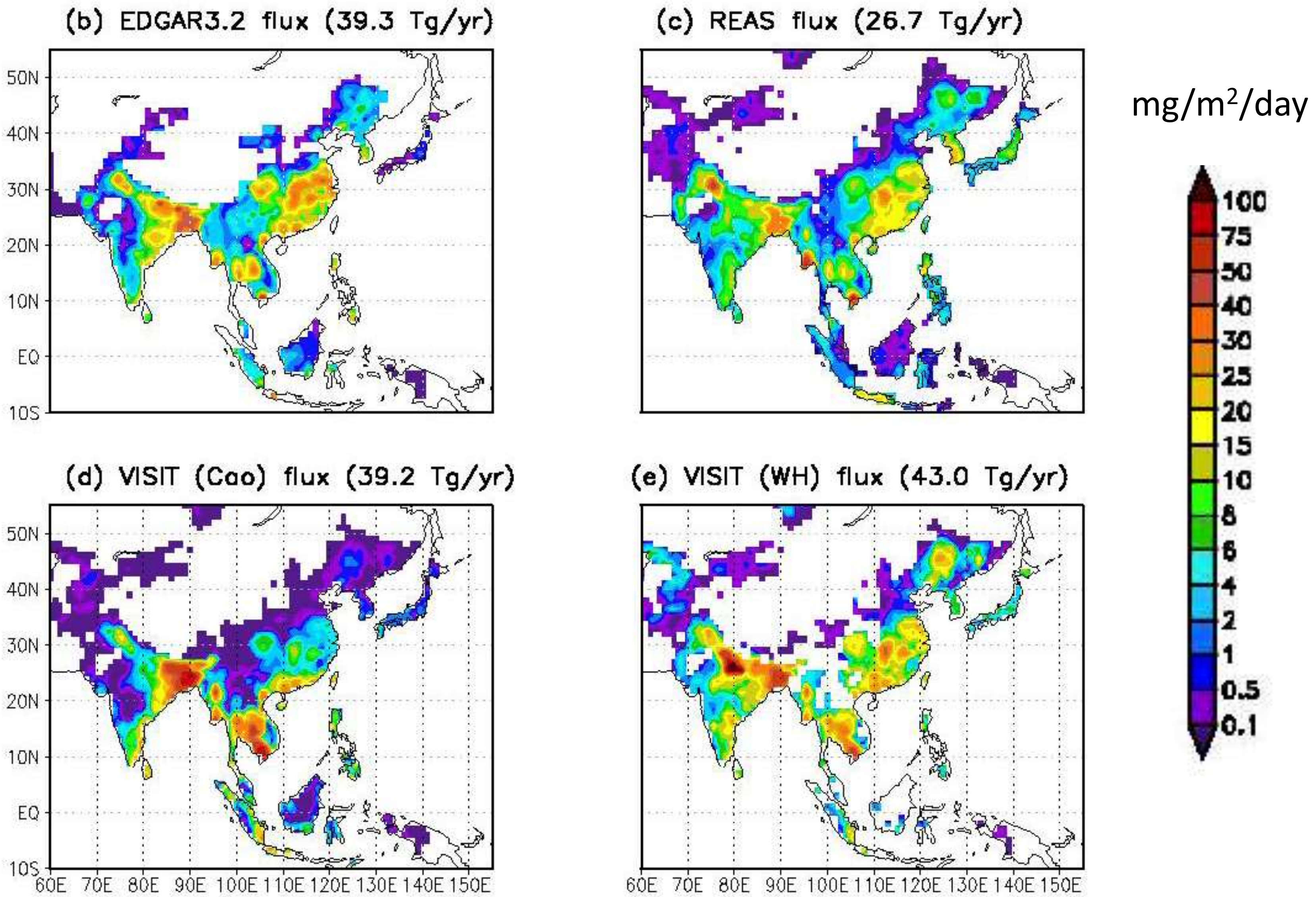


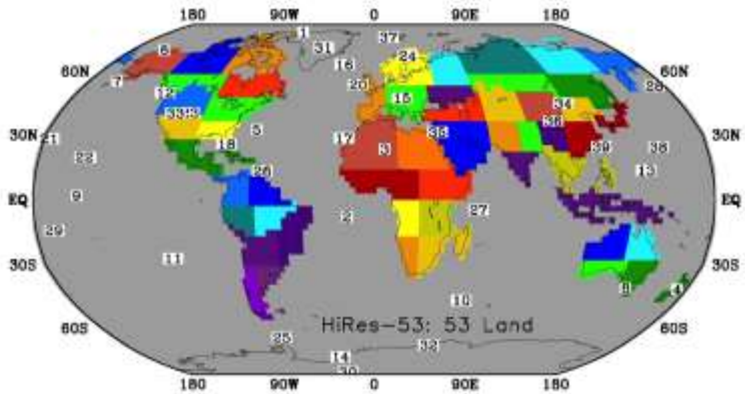
Umezawa et al., Tellus, 2014

CH_4 flux from rice fields: uncertainties in emissions



Patra et al., 2012

CH_4 emission trends – East Asia vs. the Tropics

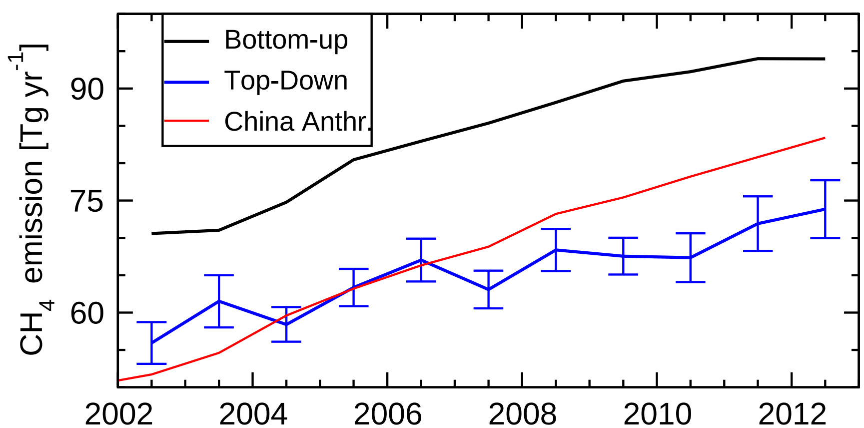


$$C_S = (G^T C_D^{-1} G + C_{S0}^{-1})^{-1}$$

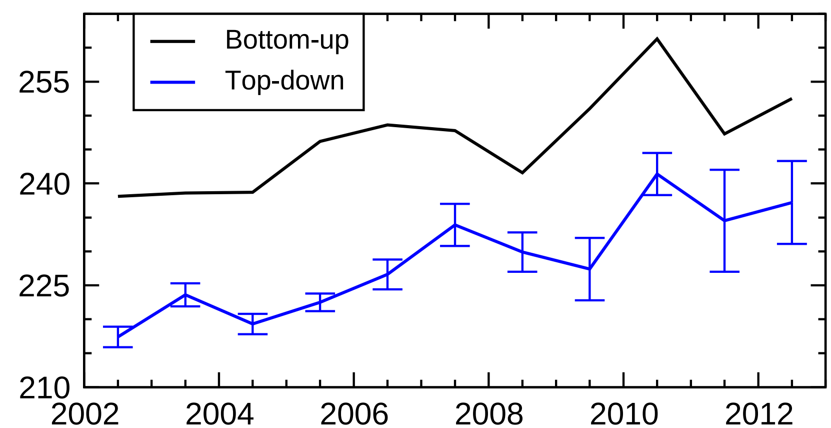
$$S = S_0 + \left(G^T C_D^{-1} G + C_{S0}^{-1}\right)^{-1} G^T C_D^{-1} (D - D_{ACTM})$$

- S_0 = regional prior sources
- C_{S0} = Prior source covariance = 50% of region-total emission for each month
- D = atmospheric concentration data
- C_D = Data covariance = 10 ppb; 5 ppb for measurements + 5 ppb for model
- D_{ACTM} = ACTM simulation using S_0
- G = Green's functions for regional source-receptor relationships

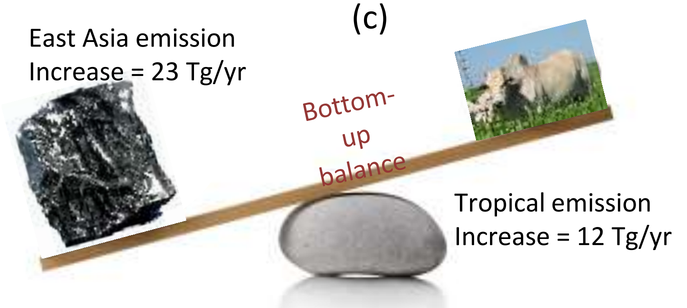
(a) East Asia: China, Japan, Korea

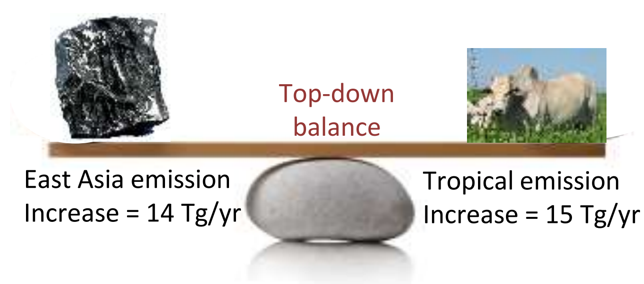


(b) Tropical Land

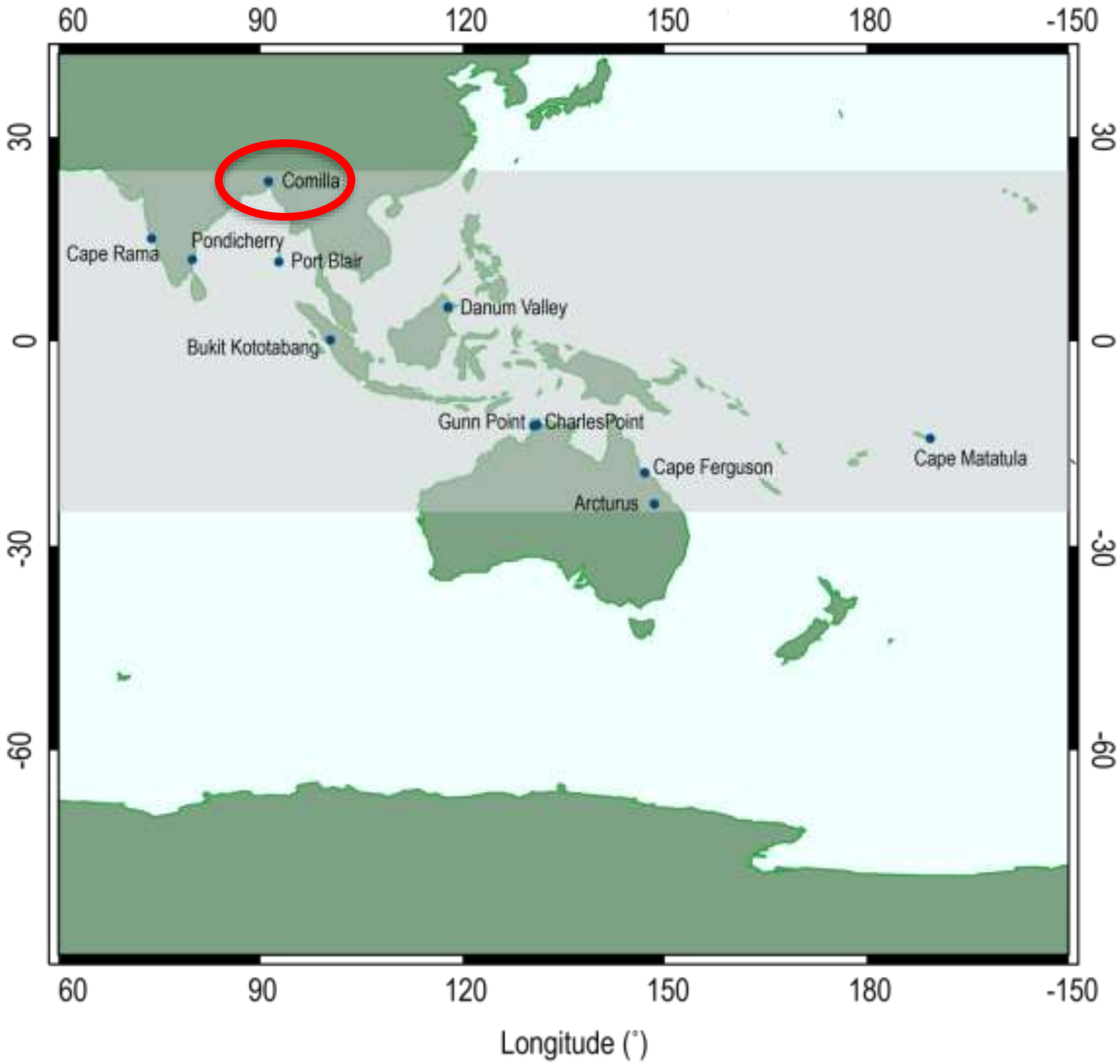


(c)





Global and Asia-Australian Regional GHGs Network



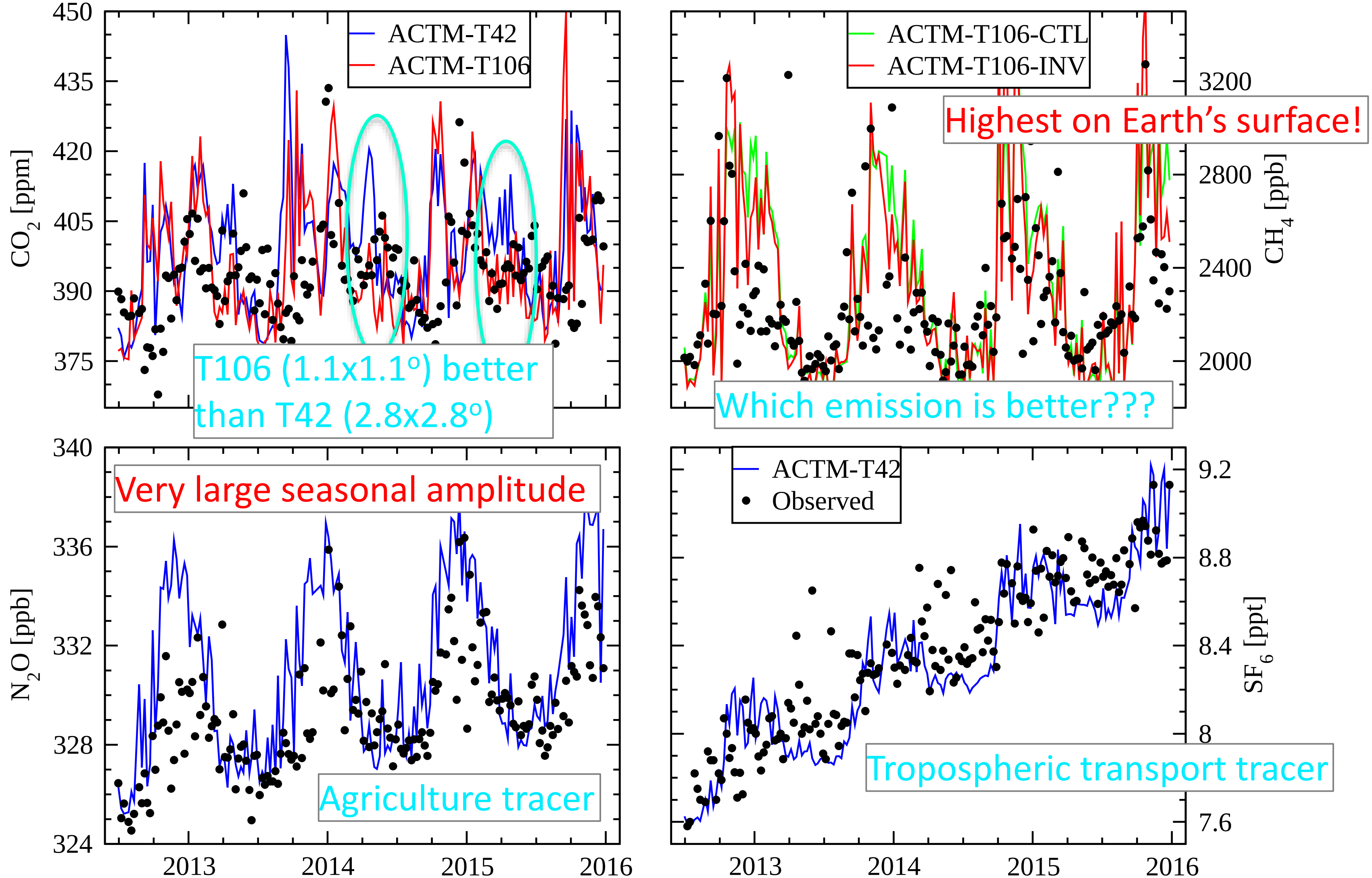
Courtesy of: Marcel van der Schoot, Pep Canadell

JAMSTEC established site in collaboration with Dhaka Univ/NIES


Observatory of Bangladesh Meteorol. Dept.
Comilla (23.45°N, 91.20°E)

Funded by:
Asia-Pacific Network (APN): Patra and Canadell
Ministry of Environment, Japan (PI: S. Hayashida)

Analysis of Comilla measurements using ACTM



Nomura et al., work in progress

Conclusions

- Variations of GHGs concentrations near the Earth's surface and in the upper troposphere are strongly affected by monsoon

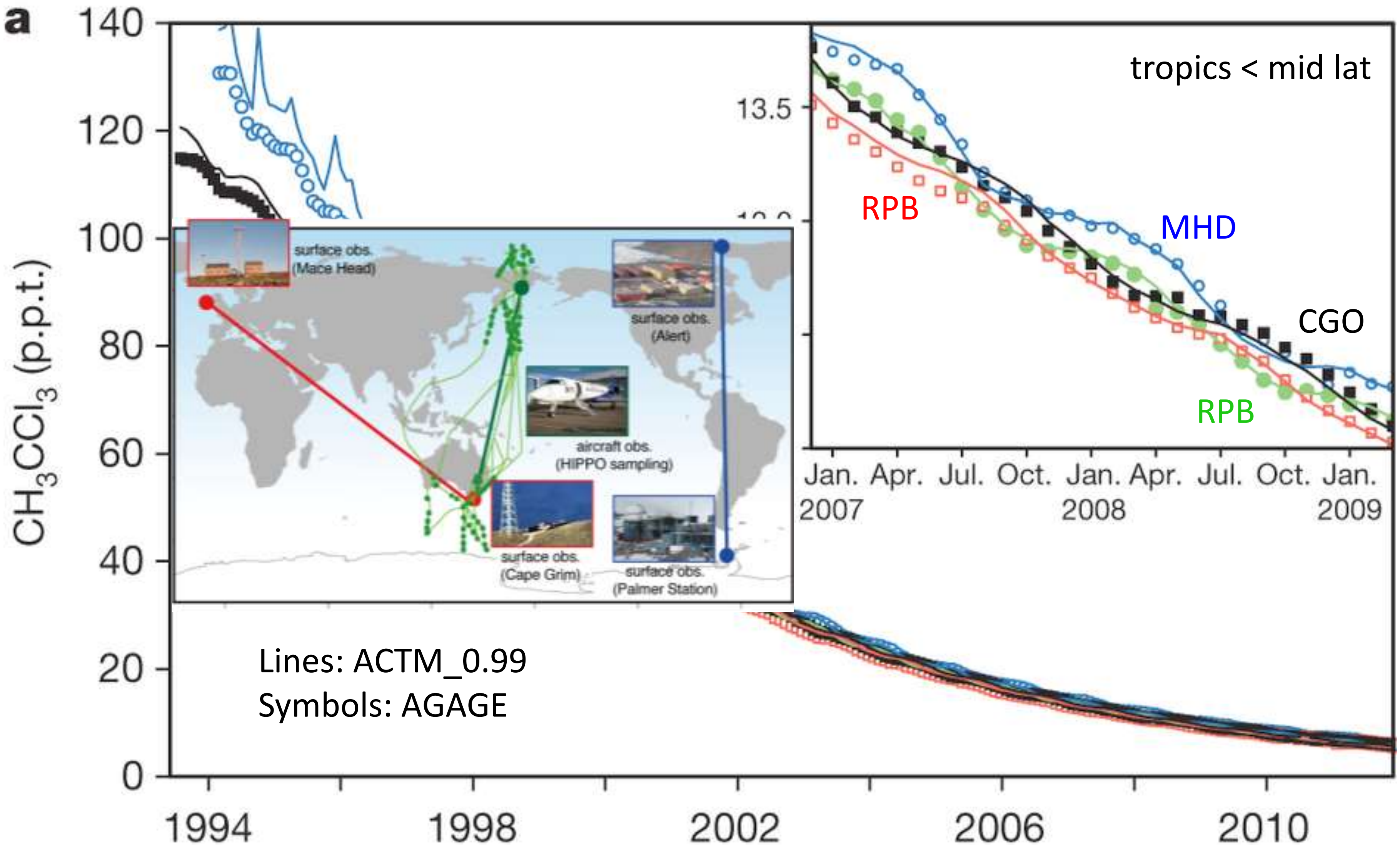
- Transport of CH_4 emission signals from South Asia can be observed by aircraft measurements over Japan (South and East Asian Transport Corridor - SEATC)

- Emissions of CH_4 by inventories are overestimated for China (East Asia) and the tropics – a conclusion following characterisation of OH

- New measurements from Comilla, Bangladesh are promising for separating contributions from emission vs transport patterns on high CH_4 over the eastern IGP

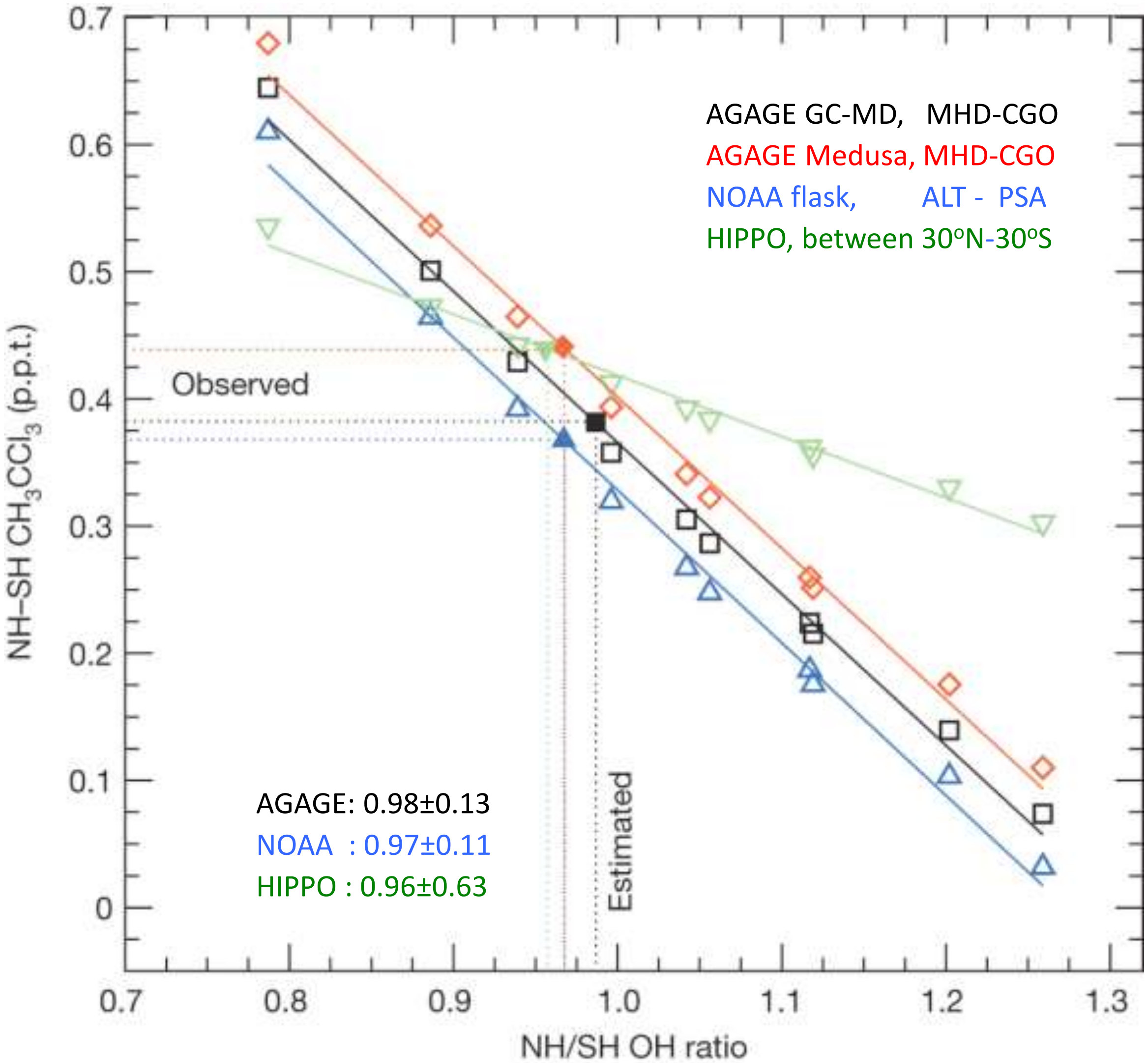
Thank you

Temporal evolutions of CH_3CCl_3 in the atmosphere



Patra et al., Nature, 2014

Various OH fields with different NH/SH OH ratios



Method	NH/SH ratio	Analysis of period	Reference
^{14}C-CO, box model	Significantly less than 1	1989-1990	Breninnkmeijer et al., 1992
CH_3CCl_3, box model	0.87*± 0.15%	1998-1999	Montzka et al., 2000
CH_3CCl_3, 3-D model	~ 0.98	1991-2000	Krol and Lelieveld, 2003
ACCMIP – IPCC AR5, full Atmos. Chem. model	1.28±0.10 (range: 1.13 to 1.42)	1980-2010	Naik et al., 2013
CH_3CCl_3, 3-D model; transport validated	0.97 ± 0.12	2004-2011	Patra et al., 2014

ACAM-2017 notes

- **Monday Morning -2**
- **Geywui Wang : PNAS 2016**
  - $SO_2 + OH + M$ (gas phase reaction rate is slow tau~1week), SO_2+H_2O_2 in aqueous phase reaction is very fast
  - SO_2 oxidation by NOx is neglected in text books, but in China NO_2 and NH_3 are high (compared to say USA)
- **Puerto: CO, O3 from Nepal**
  - Daily PBL height (ECMWF) is used for time series analysis – doen't make sense (Q.)
  - Modelling work? (Crawford) It seems inventories are 4-5 times lower than that is needed for matching model with obs (Mark)
- Abdus Salam
  - Air pollution cost 1% GDP grouth
- Gong: Isoprene and its oxidation
  - Nearly 40% O_3 is produced by OH+Isoprene reaction at the Nangling site
- Pratima Gupta: Emission and depositio of Black Carbon in the IGP
  - How representative?
- Fahim Khokar: Lohore smog(ke)
  - Delhi smog formed within 30 min in one day of Nov (pictures between 3:30pm – 4pm)
  - 80% crop residus are cleared through open burning,

- **Monday Afternoon 1**
- Helen Worden – MOPITT 17 years
  - The trends from MOPITT (decreasing) & MLO (increasing) CO are not consistent.
- Papori Dahutia : good analysis covering the East India/Bangladesh/Bhutan – aerosol vertical profiles (WRF-Chem run for her and Abdus Salam, Dhaka univ)???
- Crawford : HAM-AQ research opportunuty ; installation of Pandora instrument, upwad looking O_3, NO_2 instrument

- **Monday afternoon 2**
- Harder (MPI) : ONO experiment using HALO (see Ojha et al., 2017)
  - Injection of Nox maintains recycling efficiency for OH
  - RO_2 inside the anticyclone elevated; NOx increased due to lightning by about 30%
- Elliot Atlas - POSIDON
  - Organic Halogens, VSLS, CH_3I, Cl, ….
  - Large variabiities in VSLS compounds – how will ACTM perform?
  - Methane and NMHCs showed a few days of high values and a peak in concentration at around 15 km

ACAM-2017 notes

- **Tuesday afternoon -2**
- **Shih-Chun Candince Lung:**
  - Emission from insense sticks burning in the temples on air quality, PM2.5 exporure.
  - Based on the research results some temples in Taiwain have banned insence burning from vendors, but still allows by the visitors.
- **Guy Brasseur:**
  - Model underestimated O3 in day, overestimate NO2 in the night. This is because of the representation of PBL in the night
  - In another day, when PM2.4 reached 400 ug, but no model predicted that – underestimated by half or so
  - LES (large eddy simulation) combined with the regional models
- Jordan Schnell
  - Model simulation using CMIP5 underestimate PM2.5, but the results using CMIP6 emissions inceased modeled concentration and compared better with observations. But many a times still underestimate the observations
  - The event of Diwali is completely missed by model, because emissions are not known/inputed to model.
  - Air Stagnation Index doesn't seem to be a great predictor for air quality in the northern-central IGP region, may be a bit of link is seen over the eastern IGP
- Mary Barth
  - Clear improvement in WRF-Chem over CAM-chem global model, but WRF simulations at two resolutions of 60km and 12km were pretty similar.
  - Previous speaker said you need more emission (CMIP6) to simulate PMs ove the IGP, but WRF-Chem is fine with CMIP-5 emission inventory (unless Rajesh did some trick!)
- Prashant Dave

ACAM-2017 notes

- **Wednesday morning -1**
- **Ru-Shan Gao:**
  - South Asian monsoon anticyclone keeps the airmass wihin or transport towarsd the East and South-east Asia region
  - Aerosol layer from ATAL could penetrate upto 2 km in to the stratosphere by the monsoon anticyclone ; CESM with CARMA aerosol modlue does well in simulating the observations, at 2km above the tropopause, although there is an uverestimation of aerosol at the UT region
  - ATAL contributes 15% of the total culumn aerosol surface area in the stratosphere, but much less than the overall tropical contributions of tropospheric aerosols to the stratosphere.
- Duncan Fairlie: the BATAL campaigns
  - Balloons are launched from NARL (with A. Jayaraman)
- Michael Schwartz : MLS CO analysis using EOFs
  - This analysis showed different modes of variabilities in CO – east-west, north-south dipoles etc.
  - Now that MLS CO is now longer than 10 years (also MLS on UARS) – have you looked in to effect of Asian Monsoon on CO trends & variability in stratosphere?
- Jiali Luo : MLS & IASI CO data analysis
  - Daily maps are created using 5x5 degree Gaussian interpolation for analysis of variability
- Michelle Santee : MLS based gases climatology
  - High O3 in the UT region in MLS data is coming from the stratosphere by the Rossby wave breaking in the midlatitudes, and being transported to the ASM region
  - No correlation between IWC (convection tracer), CO and O3 variability – my impresion is that the timescale and sources are not comparable (agreed in the Q&A session)
- Jianchun Bian : SWOP – research opportunity
- Sachin Gude: WIFEX – IGIA measurements and modelling
  - How is the source of water in to the system
- Arnico Pandey : ICIMOD's atmospheric science activities
  - New sites : Lumbini, Chitwan and Ratnank
  - Long-term climate observatory : Gedu in Bhutan (building is complete) and Ihhyakamana in Nepal for GHGs, Aerisols
  - Yala glaciiers site : BC of 1100 ug/m3 in Arpil (BB??), but the value are quite high in other months too
  - Emission study for motor vehicles, before and after servicing : 1-2% of the vehicles emit 90% of BC emission; so a 10$ servicing can reduce emissionn by 90% 800,000 2-wheel and 150,000 4 wheel drive in Kathmandu. Pulling out smoking-gun vehcles from the road will make huge impact (90% reduction)

ACAM-2017 notes

- **Thursday morning -1 (No Indians arrived the venue until 8:40, even after delaying the start, as audience)**
- Simone Brunamonti, Balloon-borne measurements
  - Aerosols, water vapour, ice, very thin cirrus clouds are observed
  - The ECMWF PV plots show clearly that the surf zone is located just over Nainital in November, which iwas located more north in August.
  - Measurements were also made from Lasa (at the same latitude) and afterwards from Nainital. The delay in
  - ECMWF overestimate H_2O by 0.5 ppm compard to the observations. Similarly temperature also high-biased
  - Two ways to analyse the balloon profiles for climatology; 1) just bin by pressure/alti and take mean or 2) adjust the cold-point temperature and then take the mean with reference to CPT
- Federico Fierli: How pollutants and water vapour enter the anticyclone?
  - Role of conduit (Bergeman, Fierli, 2013)
  - ISSCP gives OLR and compared with the WRF model run for the July
- Alina Fiehn (Fiehn et al., ACP, 2017)
  - Stemmler et al., 2015 ($CHBr_3$ emission using HMMOC model), include seasonal cycle; Indian ocean is a strong source of $CHBr_3$
  - They find the transport in to the stratospere did not change much for the different emission maps, from HAMMOC and Ziska et al. eventhough the emission were 3 times in HAMMOC!
- Paul Konopka: Chimney vs blower (see Ploeger et al., ACP, 2017)
  - Strong vertical transport across the troppause (chimney) and strong isentropic transport (blower) mainly occurs above the tropopuase
  - How sensitive are the results for heating rates, because there are uncertainties in heating rates between the reanalysis data, ECMWF, MERRA, JRA55 …
- Klaus Gottschaldt : Analysis of HALO data using CLaMS model
- Bärbel Vogel :
  - HCFC-22 tag tracers simulations are compared with MIPAS measurements. She used HCFC-22 emission maps looks similar to CH_4/FF CO_2 – distribution using population proxy. How will the transport efficiency change with a more realistic emission distribution??? I understand HCFC-22 has a long lifetime, but the horizontal transport may redistribute the emission signals differently before transporting up by convective transport.
- Rolf Muller : looks so similar to Vogel’s presentation

- Abhishek Misra : Isoprene emission in the IGP, using measurements from Mohali
  - Isoprene emissions are sensitive to temperature and solar radiation; WRF-Chem underestimates observed Isoprene concetrations using emissions from EDGAR, Guenther & FINN
  - How is the OCHO (Jim) OH (PKP) concentrations ? They have measurements of O_3 and OH – willl have a look how is the OH in model
- Pallavi Saxena:
  - Too low NO_x, (~20ppb?), and too low O_3 (80 ppb peak) – which doesn’t seem to be quite right for a megacity like Delhi?
- Tuan Nguyen Dinh
  - Benzene emissions increased by 3 times in Vietnam due to inrease of motor vehicle from 3 mil in 2010 to 9 mil in 2015 or some such period