What controls the seasonal cycle of columnar methane observed by GOSAT over different regions in India?

N. Chandra[1], S. Hayashida[1], T. Saeki[2] and P. K. Patra[2]

[1]Nara Woman's University, Japan

[2]Department of Environmental Geochemical Cycle Research, JAMSTEC, Japan

This is results from Atmospheric Methane from Agriculture in South Asia (AMASA) project, sponsored by MOE, Japan

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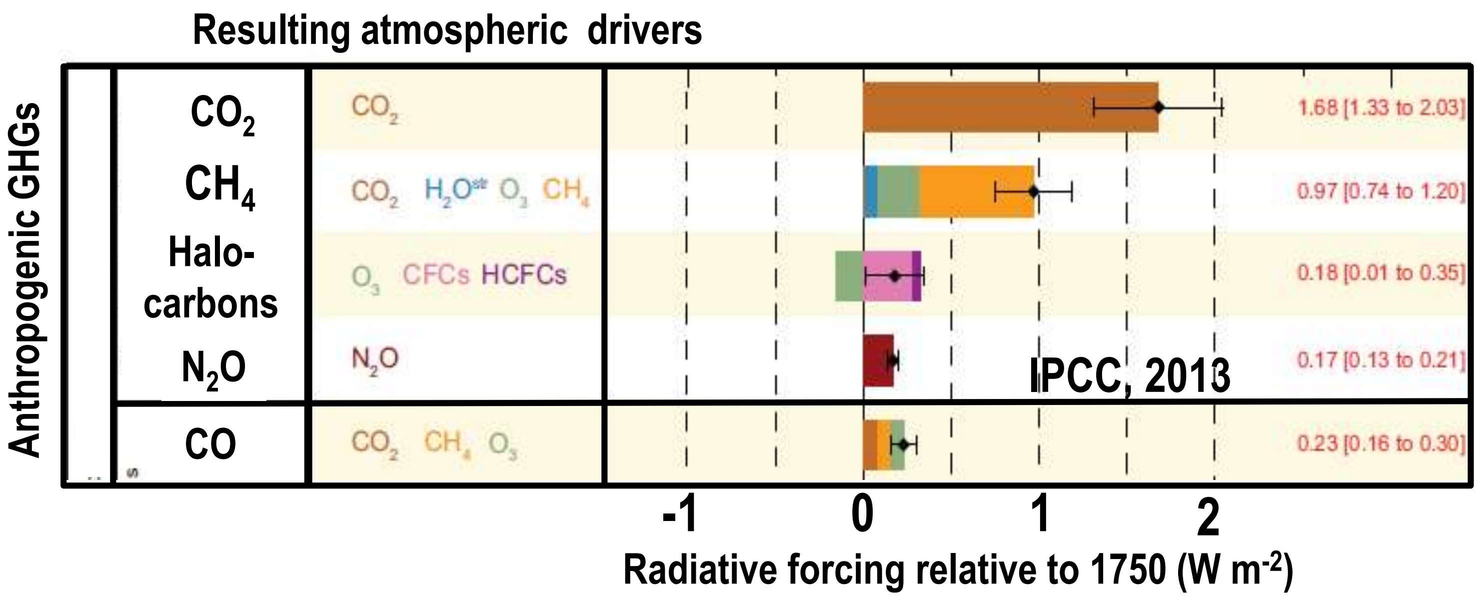
Jinan University, Guangzhou

Why should we care for methane?

- Second most important driver of anthropogenic climate change.



- Addresses climate change on time scales of decades.

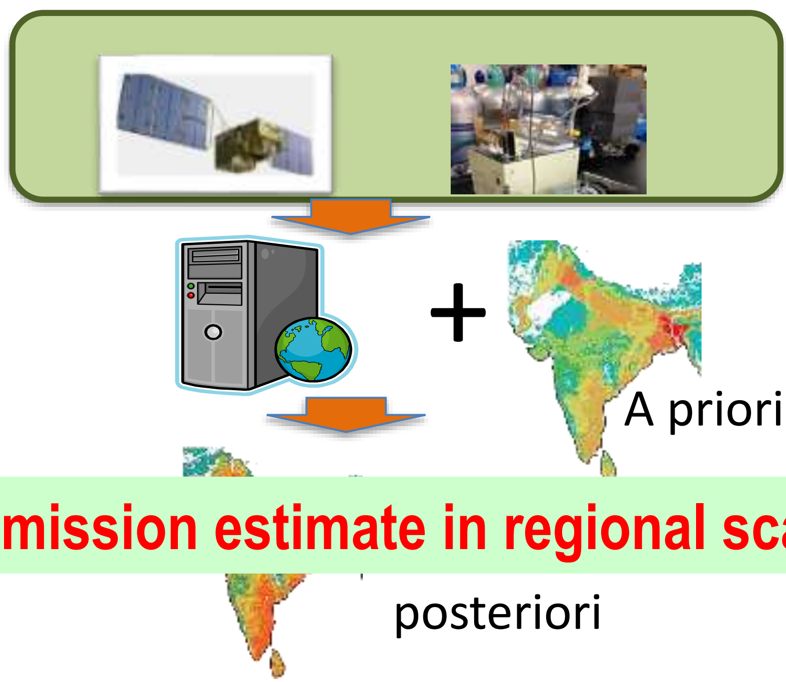
- Sectorial emissions of CH_4 remain highly uncertain, particular from Asian region due to limited observations.

AMASA

（ Atmospheric Methane from Agriculture in South Asia ）

a project sponsored by the Environment Research and Technology Development : April 2015-March 2018 Leader: Sachiko Hayashida

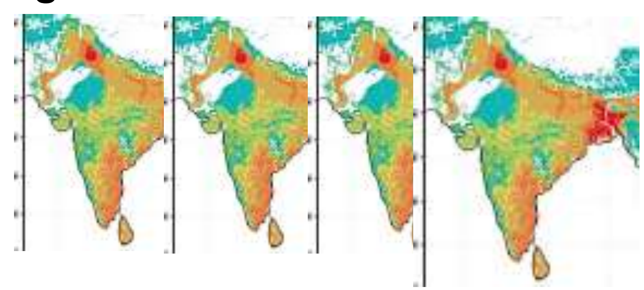
Goal 1: Improvement of Methane Emission Estimate from South Asia



Emission estimate in regional scale

Goal 2: Development of an Emission Mitigation Proposal

Mitigation scenarios from rice fields

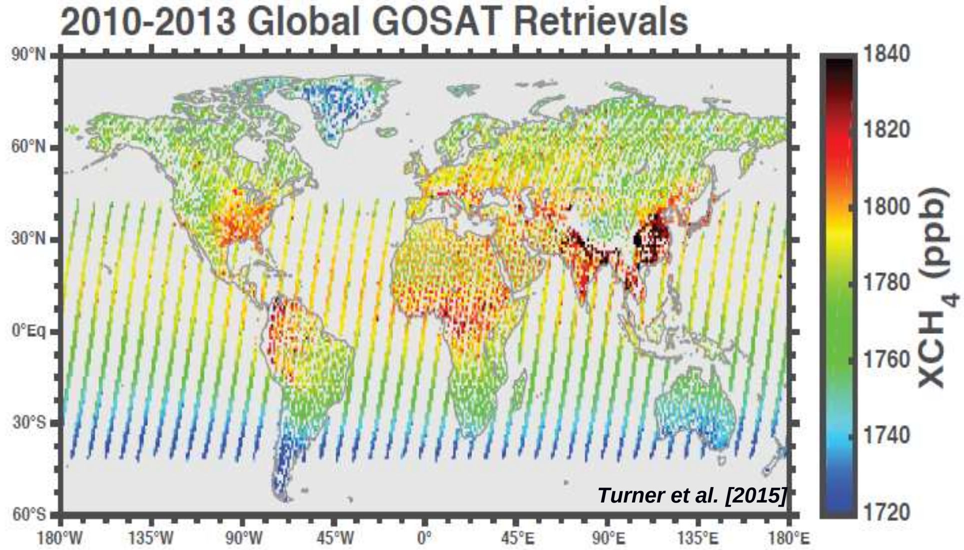


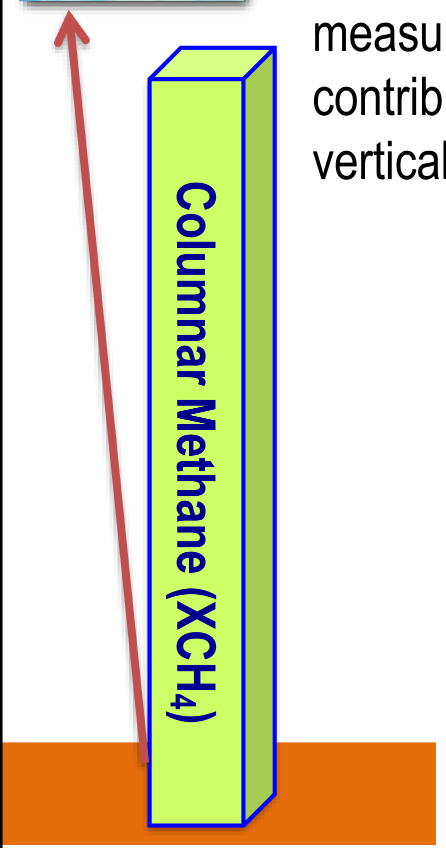
by proper water management and/or change in transplanting

Satellite measurements of XCH_4

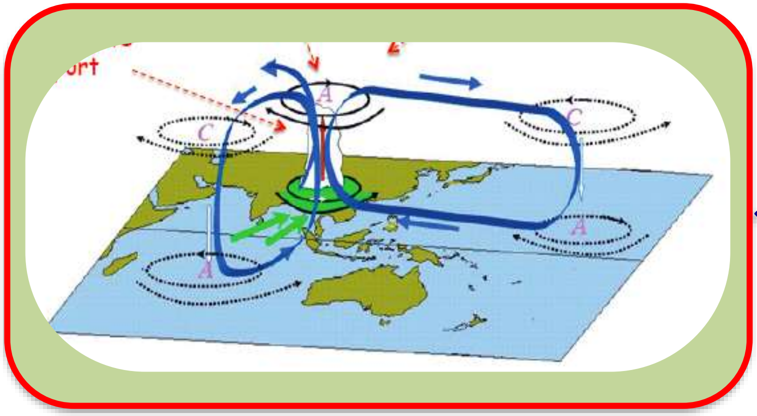
GOSAT (2009 – present)

SWIR -- XCH_4 -- Integrated measure of CH_4 with contributions from different vertical atmospheric layers.





- **High XCH_4 – High surface emissions ?**



ACTM can be used to investigate the role of transport and chemistry

Emission information could not drive straightforwardly without separating the role of transport and chemistry in the XCH_4.

Aim of this study

Understand the responsible factors for XCH_4 seasonal cycle over the Asian monsoon region.

Data Used in present study:

Period: 2011 - 2014

Observations and model: GOSAT and JAMSTEC's ACTM

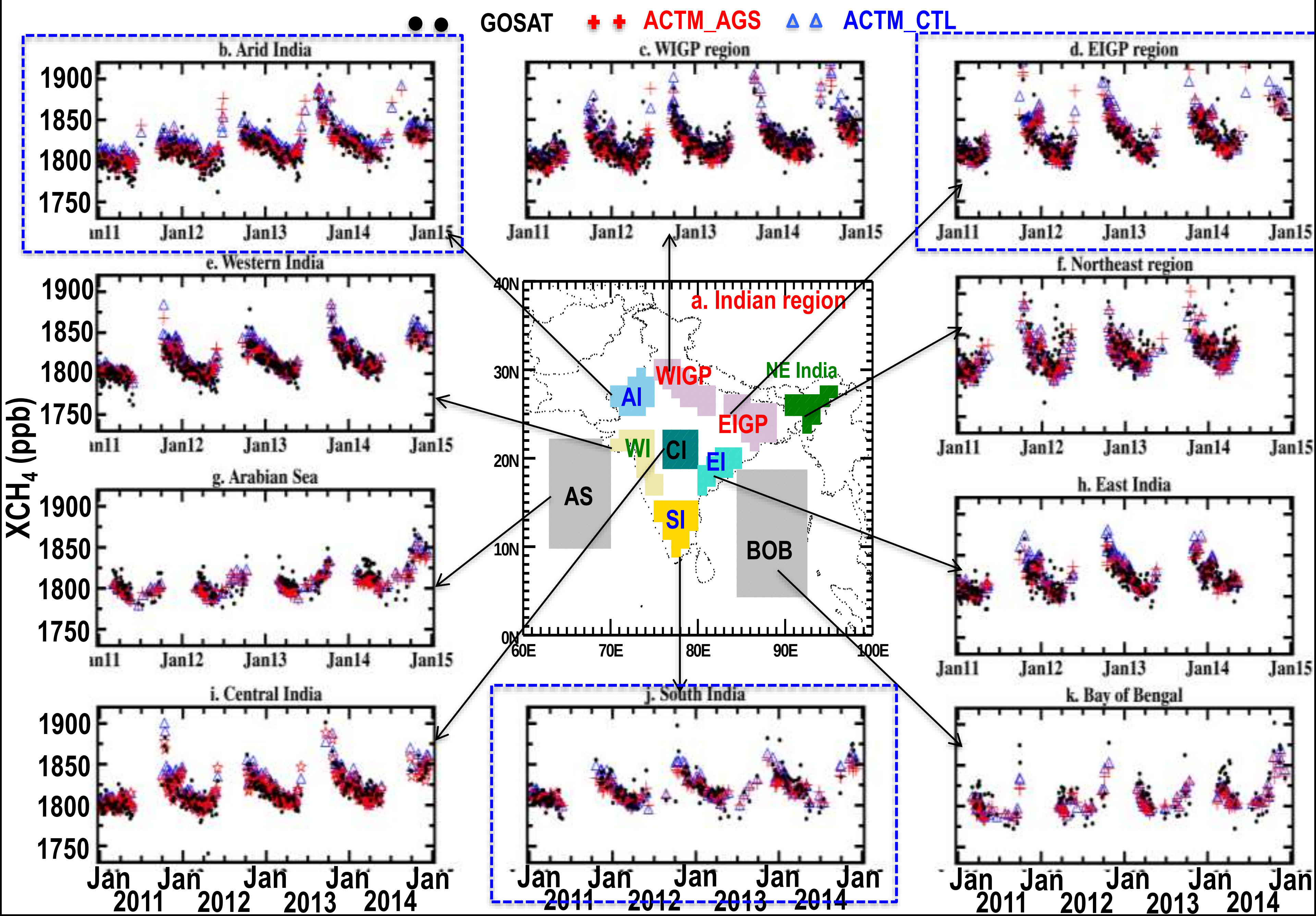
Simulations : (Anthropogenic: EDGARV4.2; Wetl. & Rice: VISIT; Termite: GISS; Bio. Burn: GFED)

Two different emission scenarios (AGS and CTL) are used to examine model sensitivity to change in the underlying fluxes in simulations of the total atmospheric column.

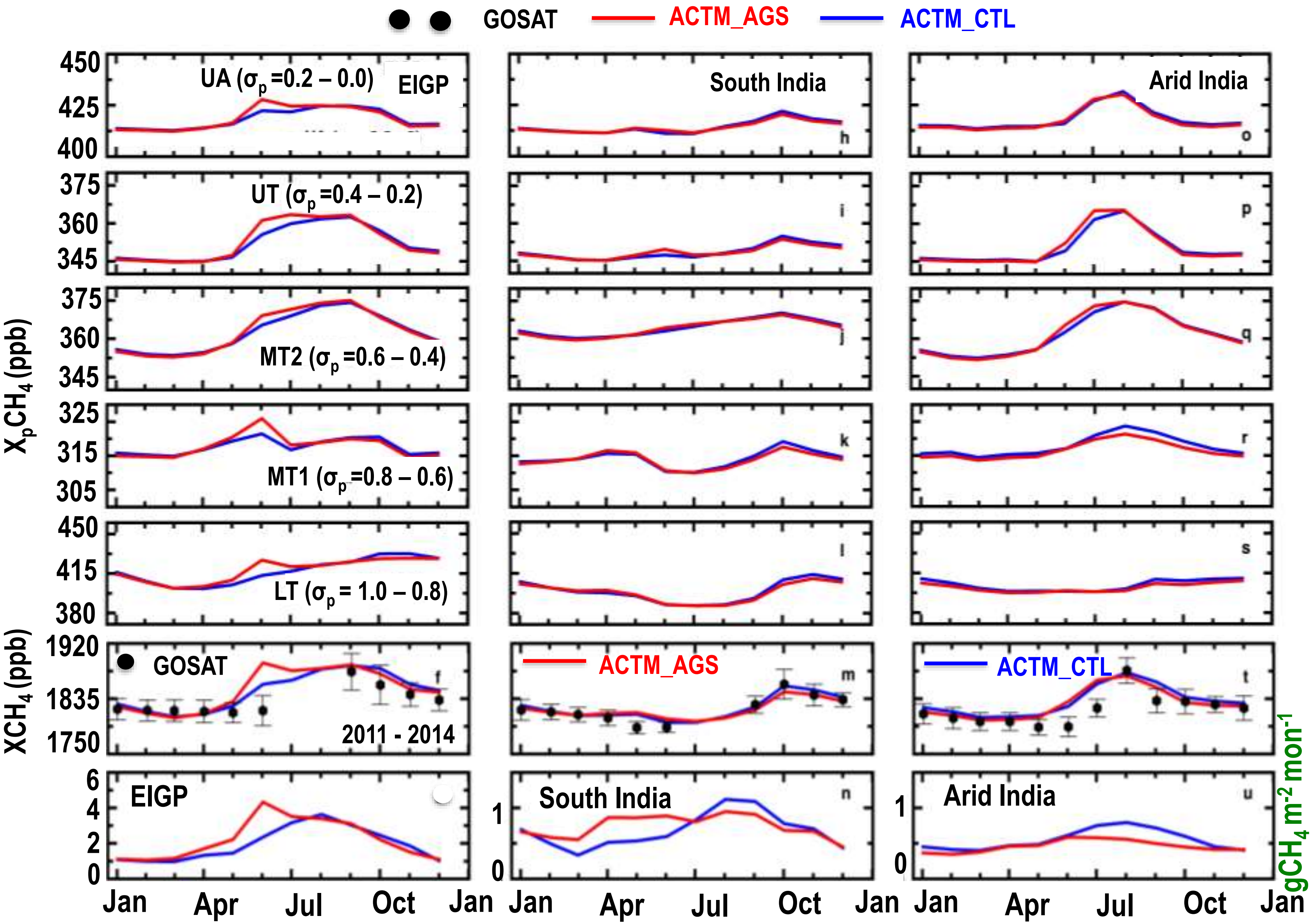
AGS: All emission sectors in EDGAR42FT kept constant at the values for 2000, except for the emissions from agricultural soils.

CTL: EDGAR32/VISIT/GISS

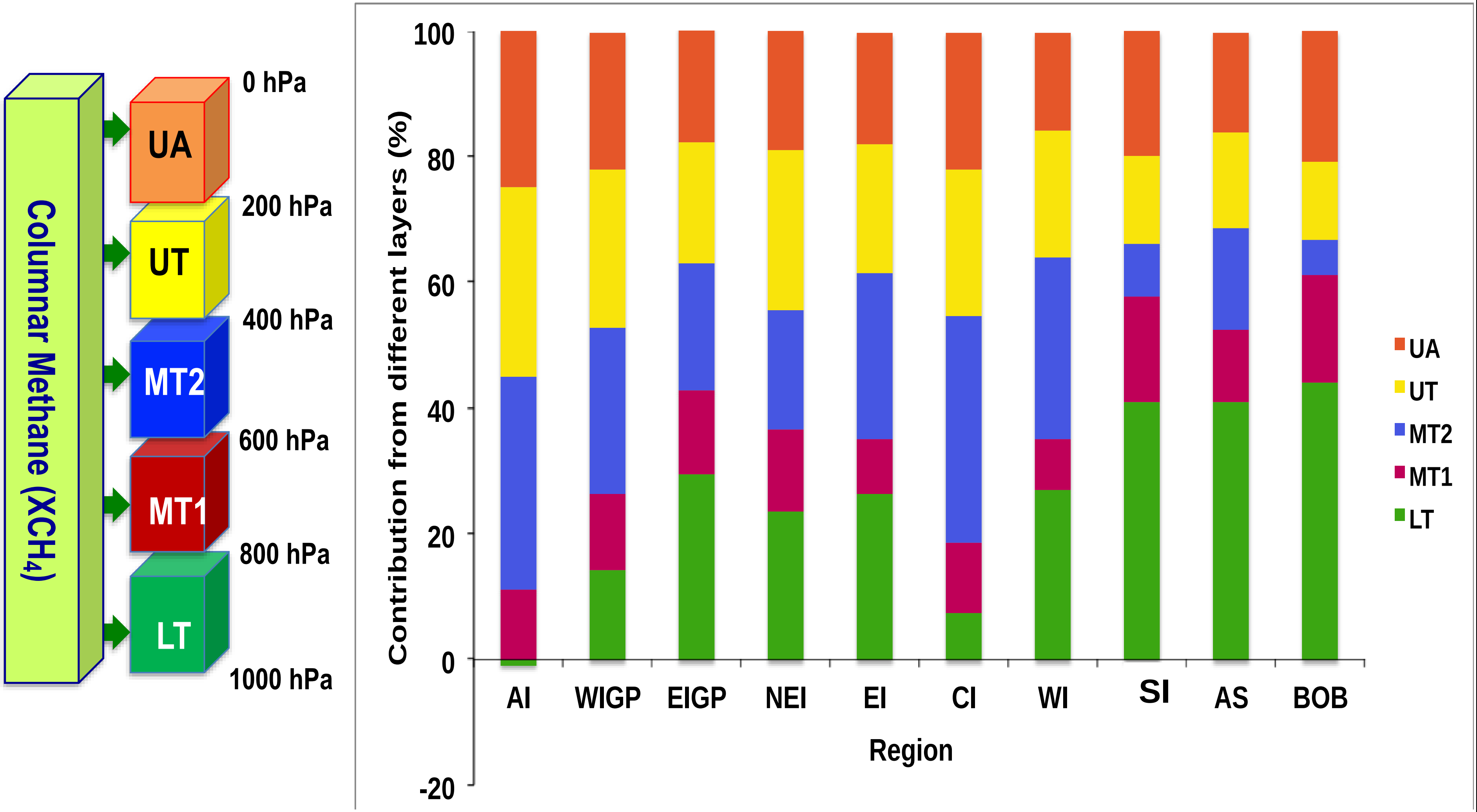
XCH_4 from GOSAT and ACTM over Indian region



Role of vertical layers in XCH4 mixing ratios

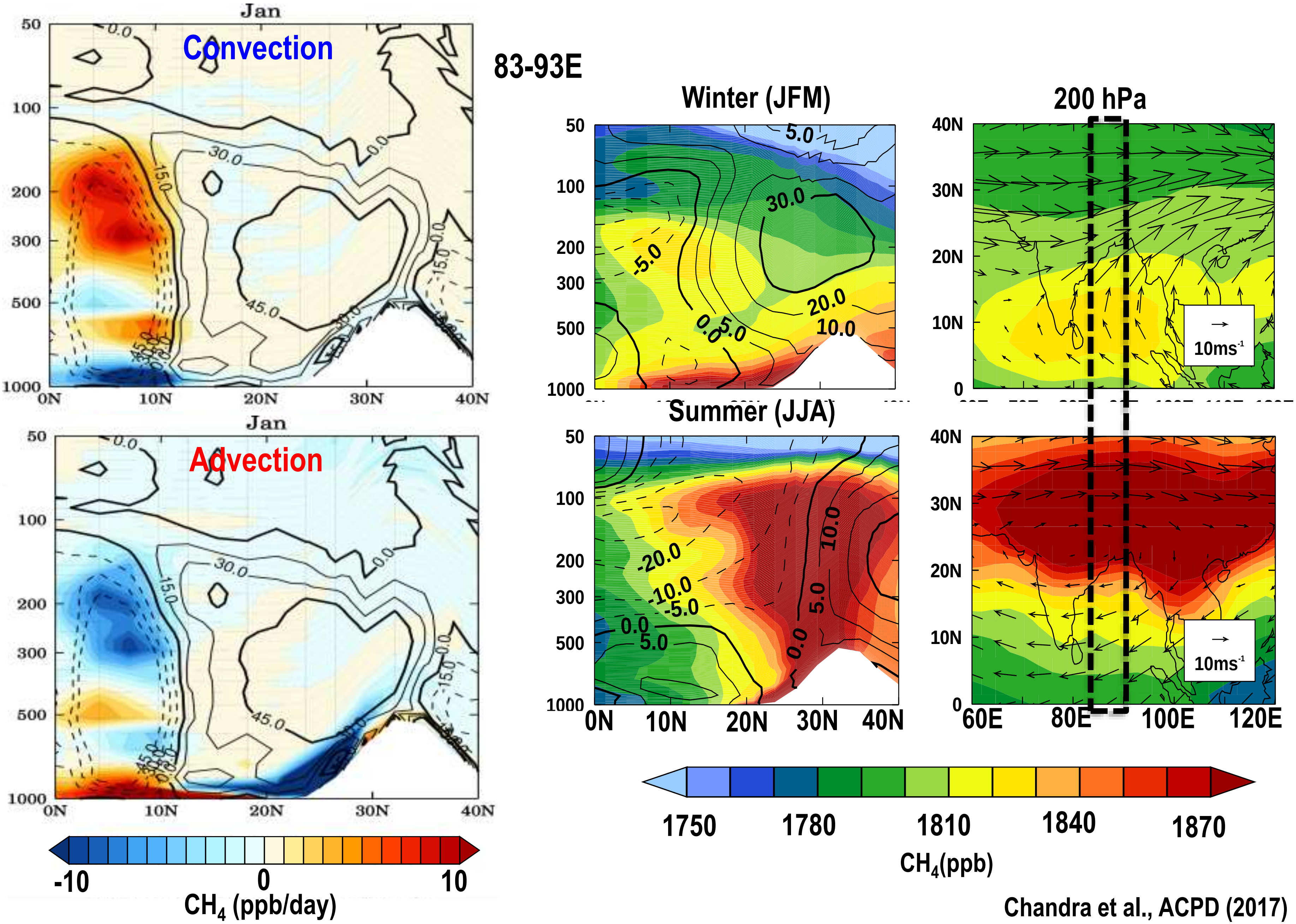


Contributions of vertical layers in XCH_4 mixing ratios



Chandra et al., ACPD (2017)

Source of higher CH_4 in the upper troposphere



Chandra et al., ACPD (2017)

Conclusion

- ✓ Both convection and advection play significant role in transport and redistribution of CH_4 over the South Asian monsoon region.

- ✓ A direct link between surface emissions and higher levels of XCH_4 can not be established straightforwardly.

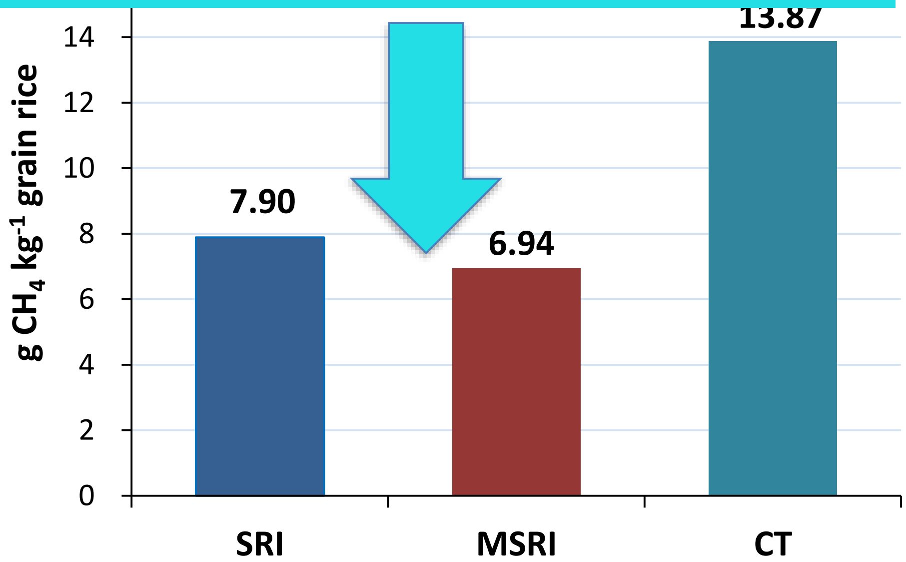
- ✓ Upper troposphere contribute strongly in the peak of XCH_4 over most of the regions lying in the northern part of India.

Thank You
for your kind
attention

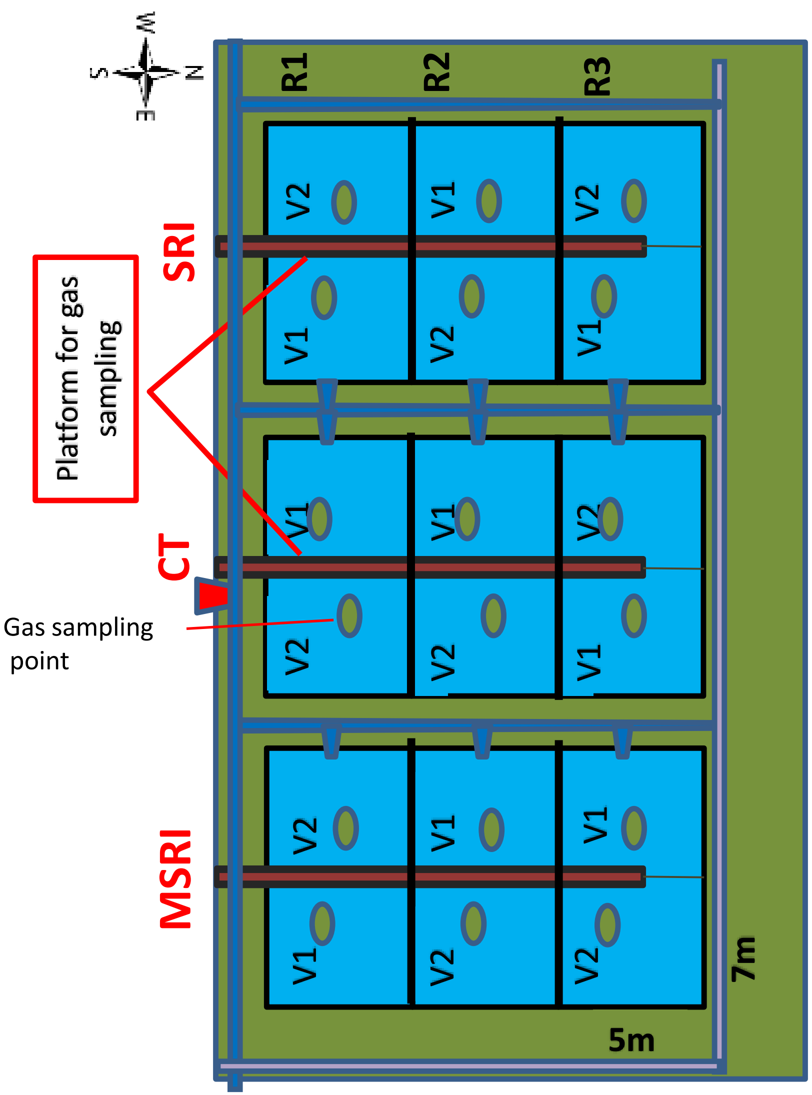
Site S: Mitigation Experiments

using alternate wetting and drying (AWD) system of rice intensification (SRI)

They succeeded to reduce CH4 emission from rice paddies ~ 50%



AWD +SRI   Conventional Transplanting

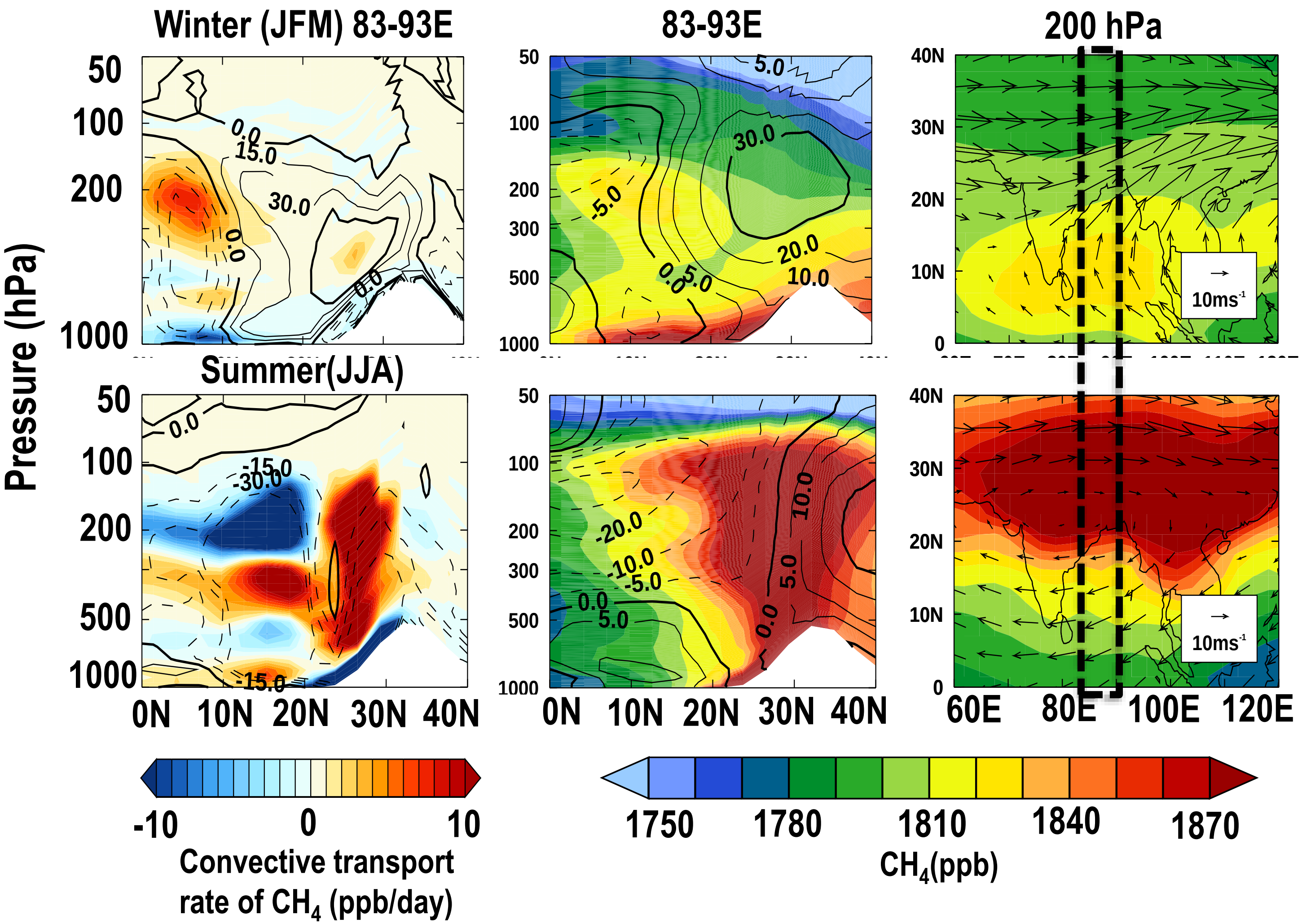


Oo et al., paper in preparation

AMASA: 6 Sub-themes

1. Analysis of GOSAT and in-situ measurements of methane (NWU).
2. Methane measurements in South Asia (NIES).
3. Mitigation options of methane emissions (NIAES).
4. Methane flux measurements in South Asia (Chiba Univ.).
5. Continuous measurements of methane by a laser Instrument.
6. Inverse Analysis of Methane (JAMSTEC).

Source of higher CH_4 in the upper troposphere

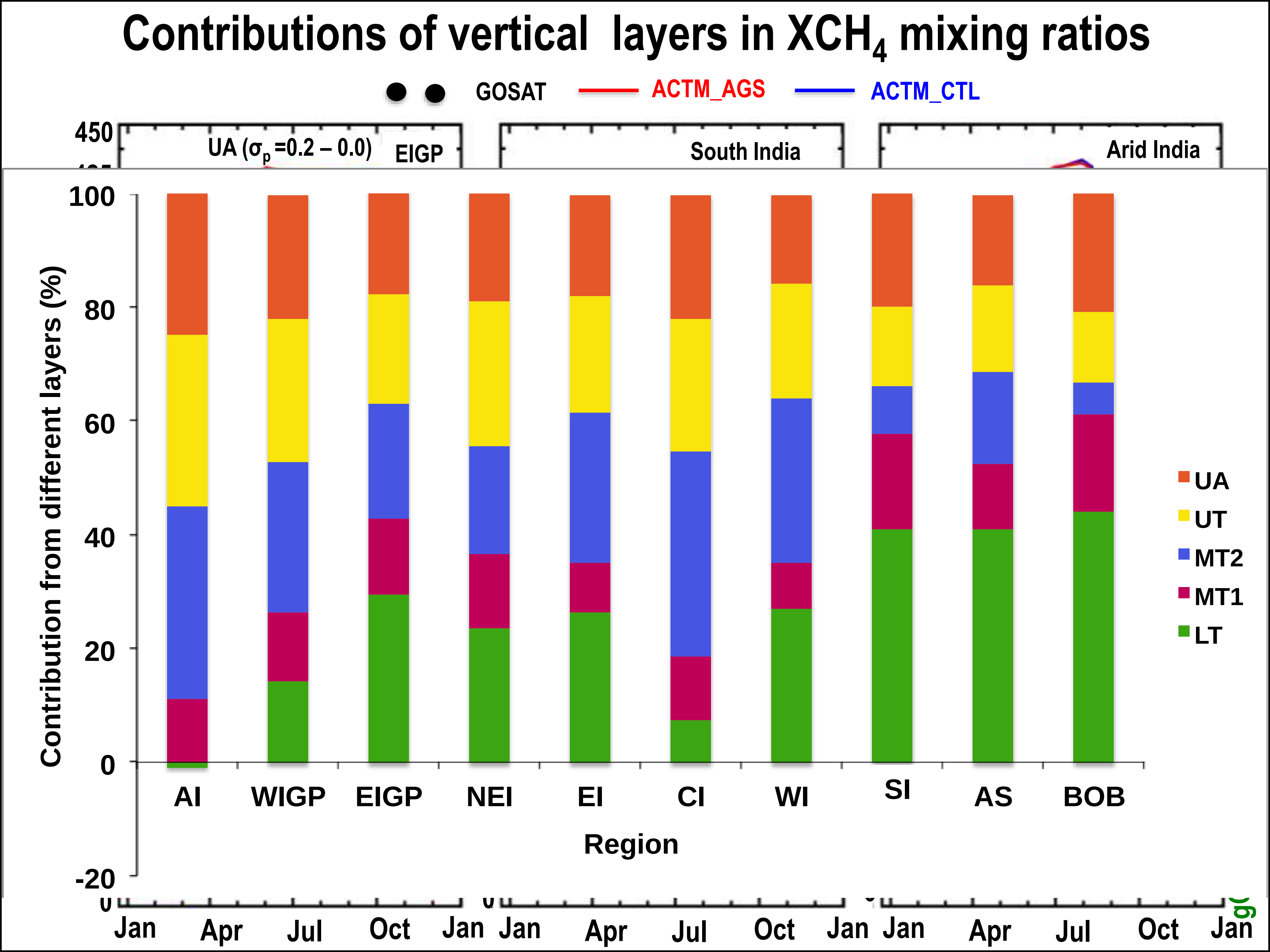


Summer -- Higher CH_4 emissions as well as higher convective transport.

Deep convection -- Inject CH_4-rich air mass into the upper tropospheric region.

Anticyclonic winds --Traps CH_4-rich air mass and further spread over the larger south Asian region.

Chandra et al., ACP (2017) (in review)



Contributions of vertical layers in XCH4 mixing ratios
GOSAT
ACTM_AGS
ACTM_CTL
450
UA (σp =0.2 – 0.0)
EIGP
South India
Arid India
Contribution from different layers (%)
100
80
60
40
20
0
-20
AI
WIGP
EIGP
NEI
EI
CI
WI
SI
AS
BOB
Region
UA
UT
MT2
MT1
LT
Jan
Apr
Jul
Oct
Jan
Jan
Apr
Jul
Oct
Jan
Jan
Apr
Jul
Oct
Jan

Calculation of XCH_4

XCH_4 is calculated from the ACTM profile using the formula $\Sigma_i\ CH_4\ (i) \times \Delta p_i$, where *i* is the model level of thickness Δp_i

$XCH_4 = \Sigma_{n=2}^{60}\ CH_4\ (n) * \ [(\sigma_p\ (n) + \sigma_p\ (n-1))/2 - (\sigma_p\ (n) + \sigma_p\ (n+1))/2]$

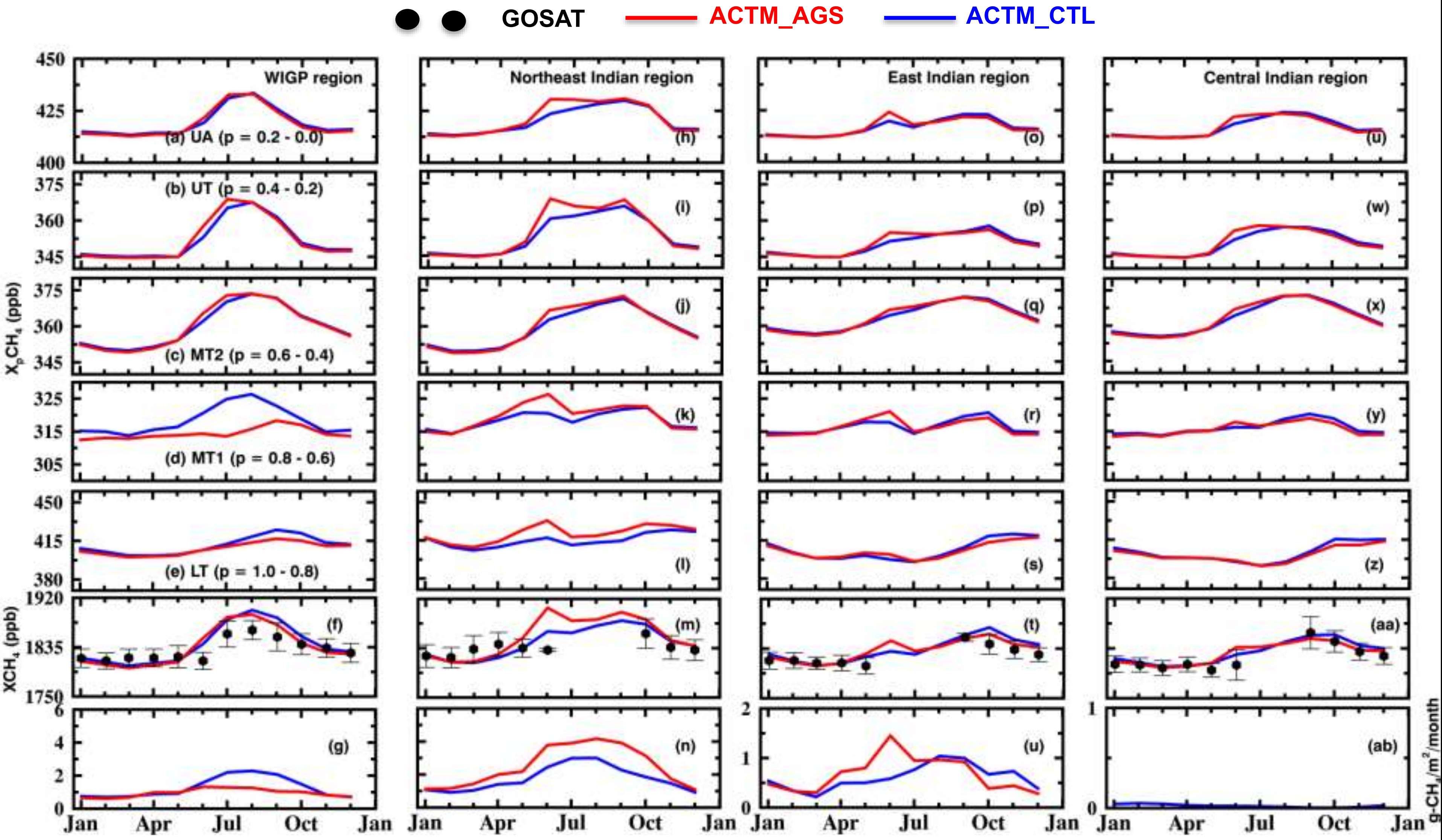
For the first layer (n =1)

$XCH_4 = \Sigma_{n=1}\ CH_4\ (n) * \ [1- (\sigma_p\ (n) + \sigma_p\ (n+1))/2]$

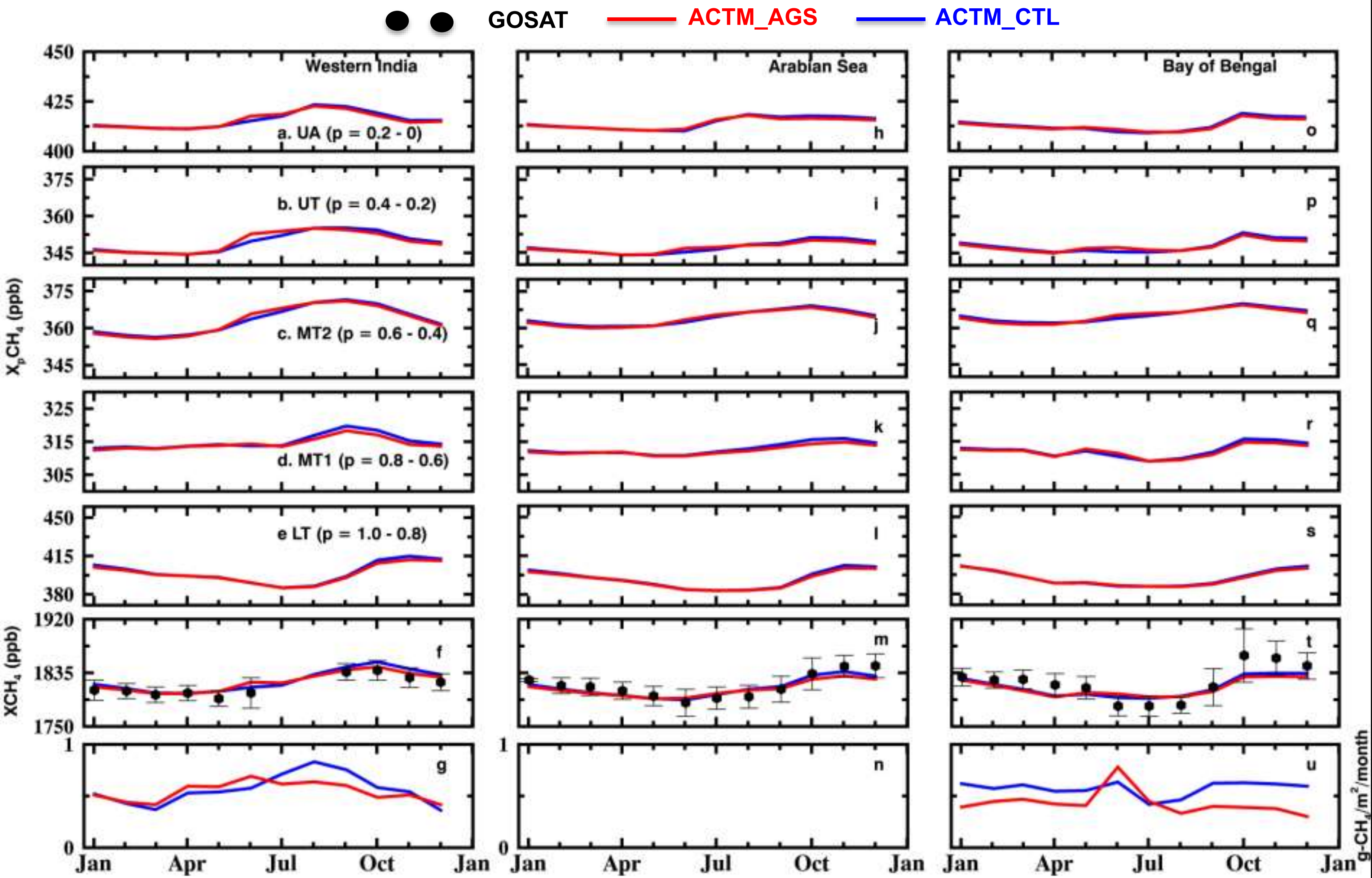
where

n = number of vertical sigma pressure layer,

σ_p = sigma pressure level

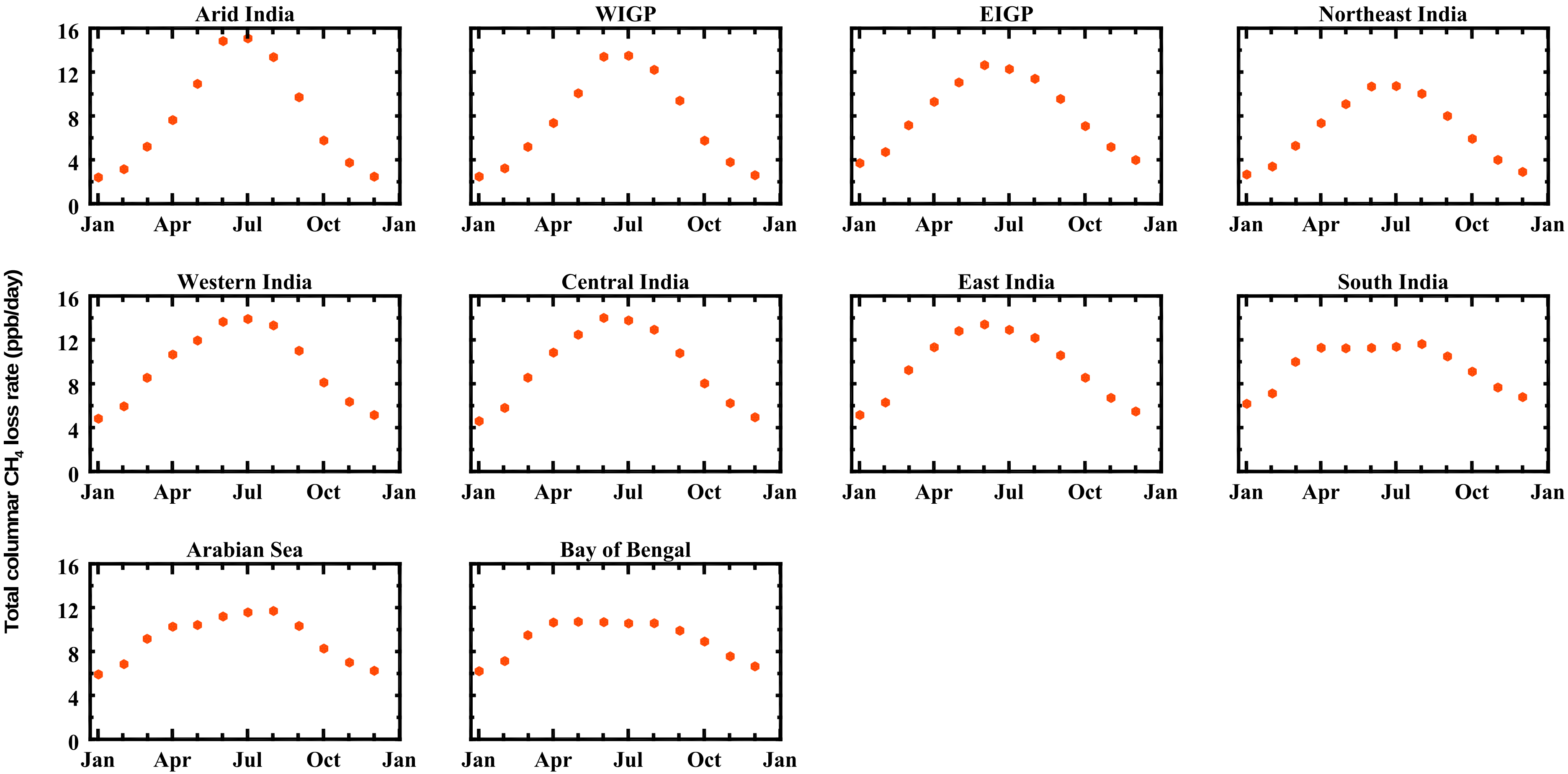


GOSAT
ACTM_AGS
ACTM_CTL
WIGP region
Northeast Indian region
East Indian region
Central Indian region
(a) UA (p = 0.2 - 0.0)
(b) UT (p = 0.4 - 0.2)
(c) MT2 (p = 0.6 - 0.4)
(d) MT1 (p = 0.8 - 0.6)
(e) LT (p = 1.0 - 0.8)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
(m)
(n)
(o)
(p)
(q)
(r)
(s)
(t)
(u)
(w)
(x)
(y)
(z)
(aa)
(ab)
X_pCH_4 (ppb)
XCH_4 (ppb)
g-CH_4/m^2/month
Jan
Apr
Jul
Oct
Jan



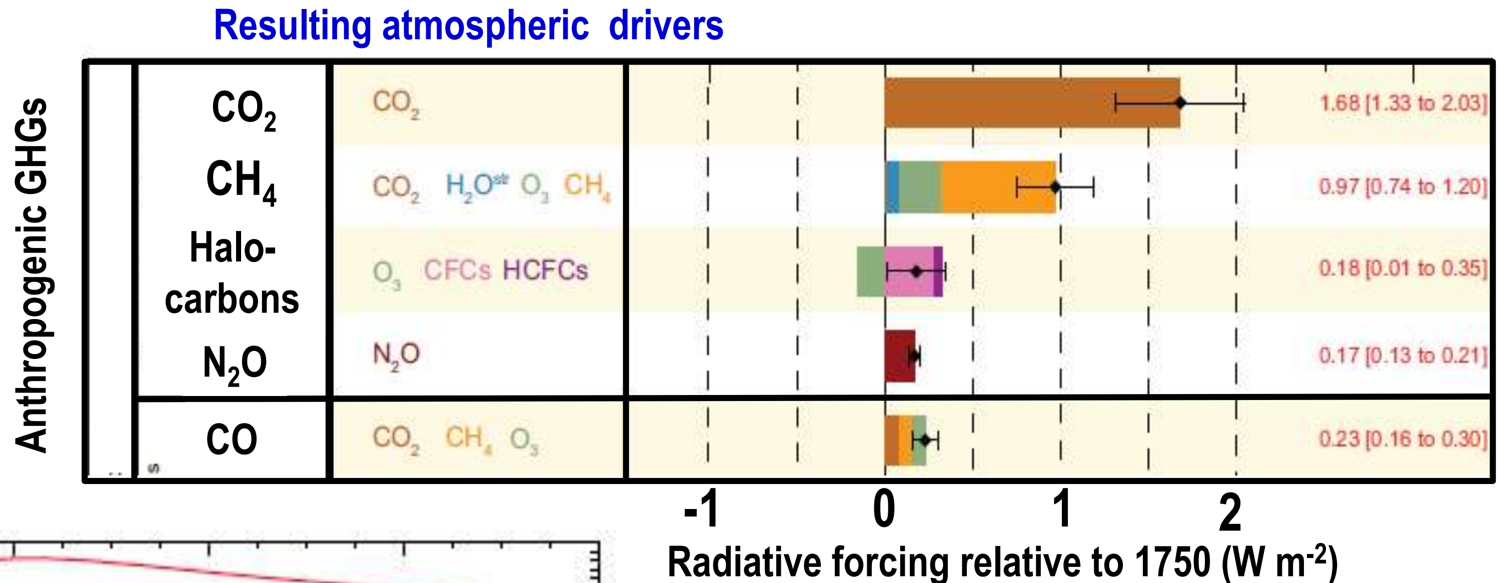
GOSAT
ACTM_AGS
ACTM_CTL
Western India
Arabian Sea
Bay of Bengal
a. UA (p = 0.2 - 0)
b. UT (p = 0.4 - 0.2)
c. MT2 (p = 0.6 - 0.4)
d. MT1 (p = 0.8 - 0.6)
e LT (p = 1.0 - 0.8)
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t
u
X_p CH_4 (ppb)
XCH_4 (ppb)
g-CH_4/m^2/month
450
425
400
375
360
345
325
315
305
415
380
1920
1835
1750
1
0
Jan
Apr
Jul
Oct

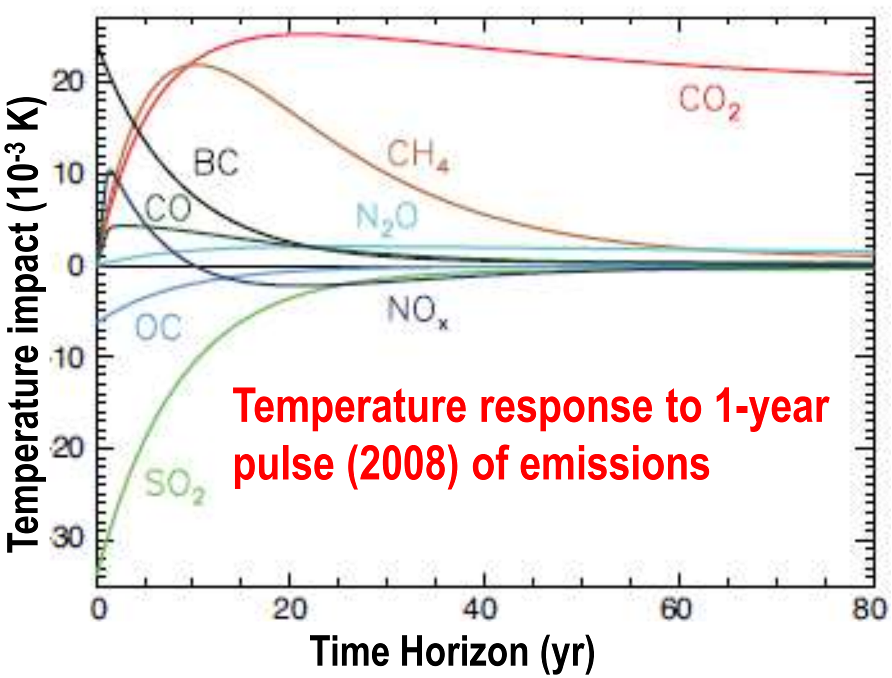
Columnar loss rate of CH4



Why do we care about methane?

- Second most important drivers of climate change.





- Importance of methane as a short lived climate forcer (SLCF).
- Curbing CH_4 emissions will more helpful than CO_2 to fight against global warming at inter-decadal time scale.

Source: IPCC, 2013

CH_4 emission : complexities and uniqueness of ACTM inversion

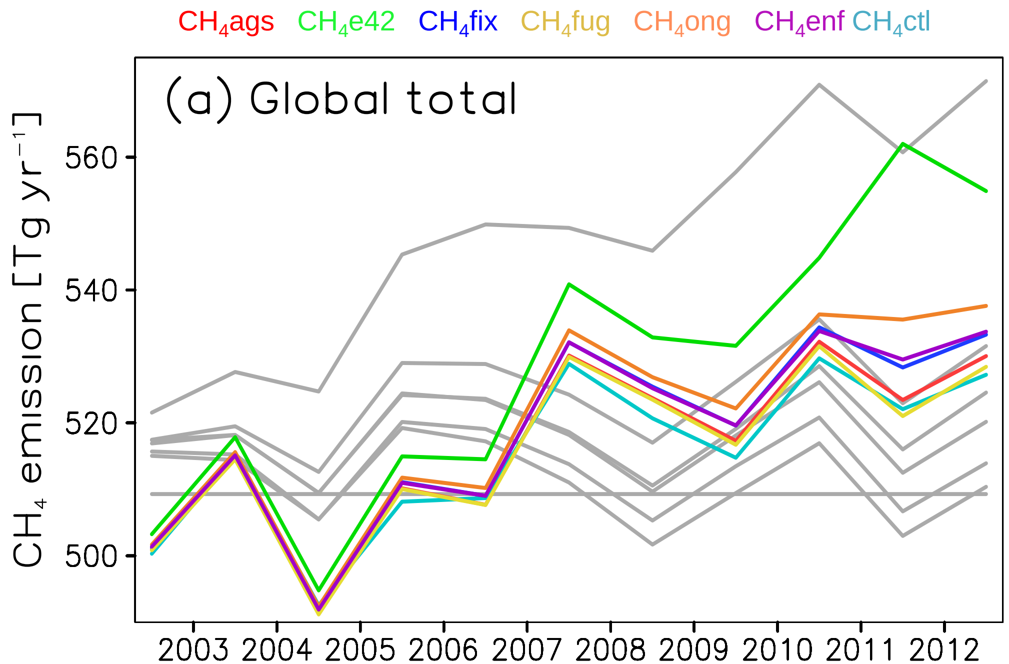
Source types

Natural:
VISIT: Wetl & Rice
GISS: Termite
GFED: Bio. Burn
SRON: Ocean
SRON: MudVolcano

Anthropogenic:
(EDGAR4.2)
IPCC_1A (transport)
IPCC_1B (Fugitive)
IPCC_2 (Industry)
IPCC_4A (Ent. Ferm.)

Soil sink: VISIT

Chemical loss:
OH: Spivakovsky/scl
Cl/O^{1}D: ACTM



Inversion results are dependent on the choice of prior flux

So inversions are run for 7 ensemble cases

The outliers are decided by independent aircraft measurements

Trends : come from Anthropogenic emissions
Variability : are mainly due to Natural emissions

Challenges

- Individual sources of CH_4 remain highly uncertain.

- In-situ observations - Improve our understanding of various CH_4 sources, but the observation stations are sparsely distributed.

Observations from space have transformed the condition from data-poor to data-rich over past 20 years.

Challenges

- Regional emissions of CH_4 remains highly uncertain particular over Asian region, which is one of the most significant areas of CH_4 emissions.

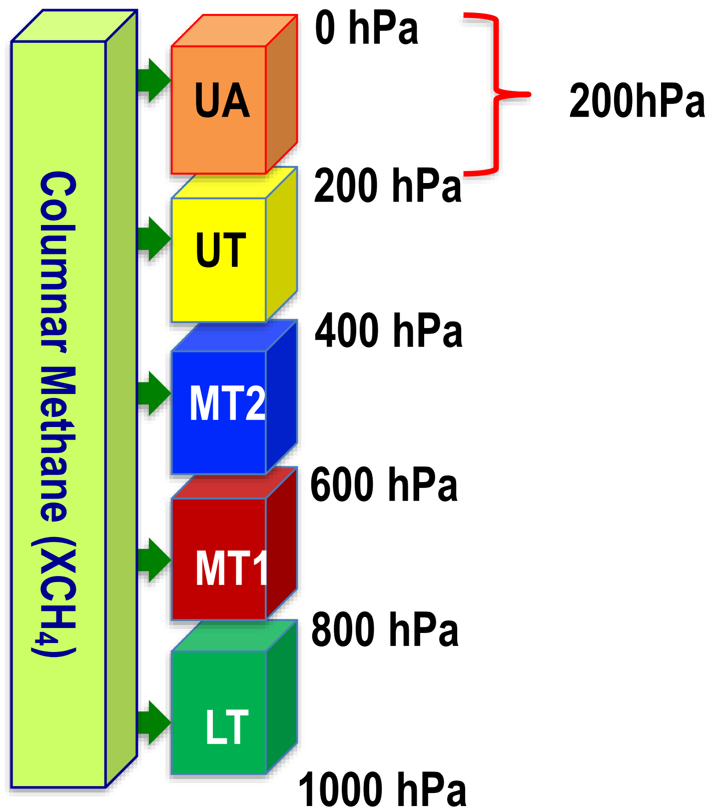
- **Where is the source of CH_4 in Asia?**

Satellite observations from space have the potential to captured the spatial and temporal variability in CH4 for most part of glob landin

Model Descriptions

Atmospheric general circulation model (AGCM)-based CTM (i.e., JAMSTEC's ACTM).

Meteorological field	Japan Meteorological Agency reanalysis fields (vr., JRA-55).
Anthropogenic	EDGAR42FT2012 (2013)
Wetlands and rice paddies	VISIT terrestrial ecosystem model
Biomass burning	Goddard Institute for Space Studies (GISS) and Global and Global Fire Emission Database (GFED) version 3.2
Resolutions	~2.8 × 2.8° horizontal and 67 vertical sigma-pressure levels
Atmospheric molar fractions of CH_4 have been simulated using an ensemble of 3 cases of a priori emission scenarios .	
AGS	All emission sectors in EDGAR42FT kept constant at the values for 2000, except for the emissions from agricultural soils.
CTL	EDGAR32/VISIT/GISS



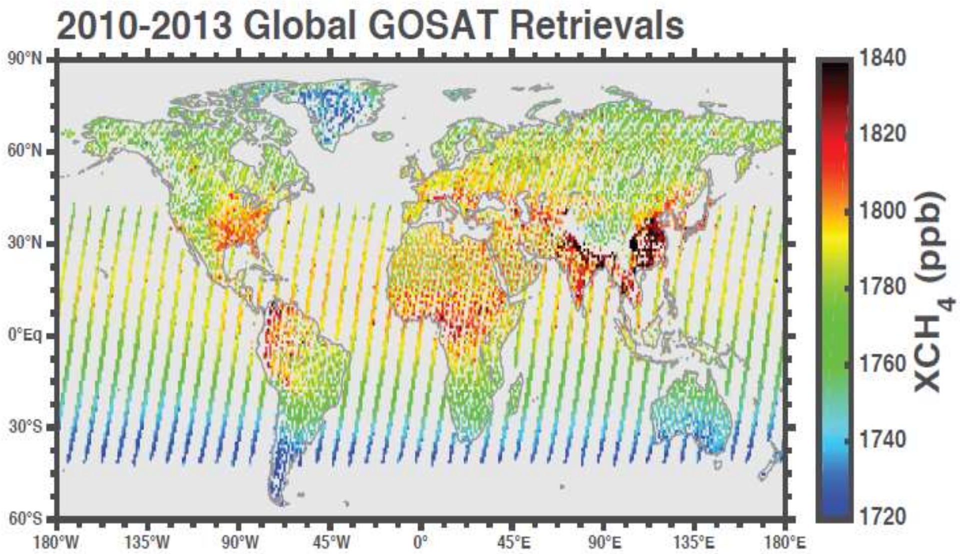
Columnar Methane (XCH_4)
UA
UT
MT2
MT1
LT
0 hPa
200 hPa
400 hPa
600 hPa
800 hPa
1000 hPa
200hPa

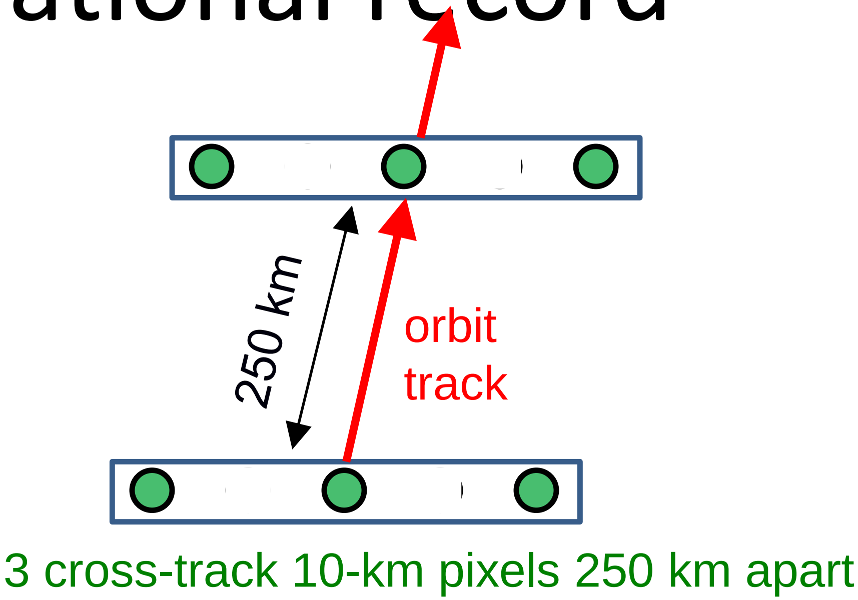
Methane should be part of climate policy …but for reasons totally different than CO_2

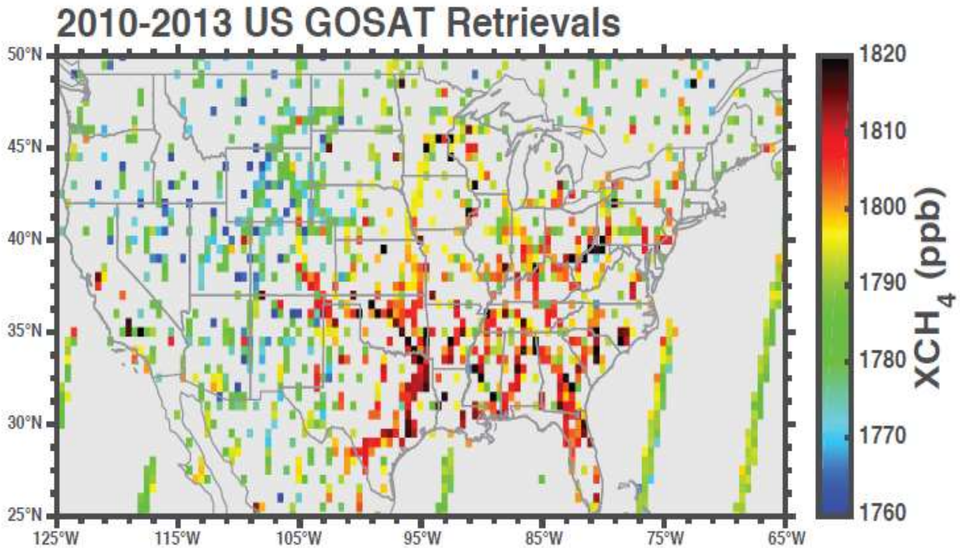
- It addresses climate change on time scales of decades – which we care about
  Loss of Arctic sea ice, seal level rise, rain during ski season
- It has air quality co-benefits
  Methane is a major precursor of background tropospheric ozone
- It is an alternative to geoengineering by aerosol injections
  Both address near-term climate change – which do you prefer?
- Reducing methane emissions can be easy to do and make money
  Fix leaks from oil/gas super-emitters, capture methane from landfills…

Climate policy should not use a single time horizon for metrics;
reporting both 20-year and 100-year GWPs would be a simple solution

The GOSAT observational record







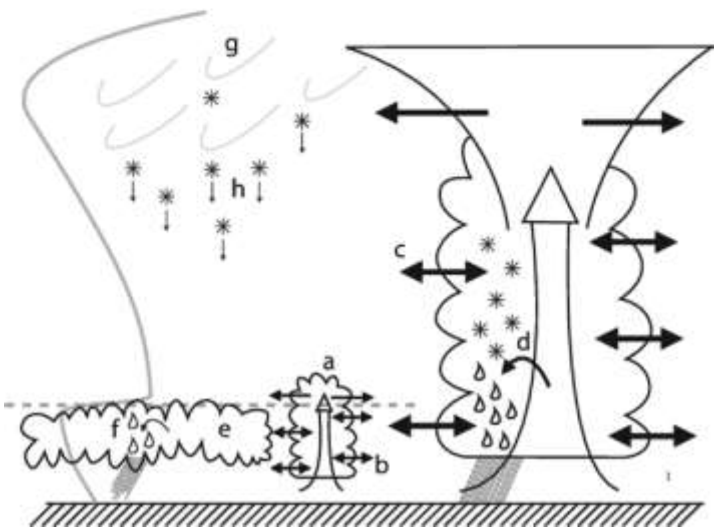
- CO_2 proxy retrieval [Parker et al, 2011]
- Mean single-retrieval precision 13 ppb
- Use here data for 6/2009-12/2011

THE ART AND SCIENCE OF CLIMATE MODEL TUNING

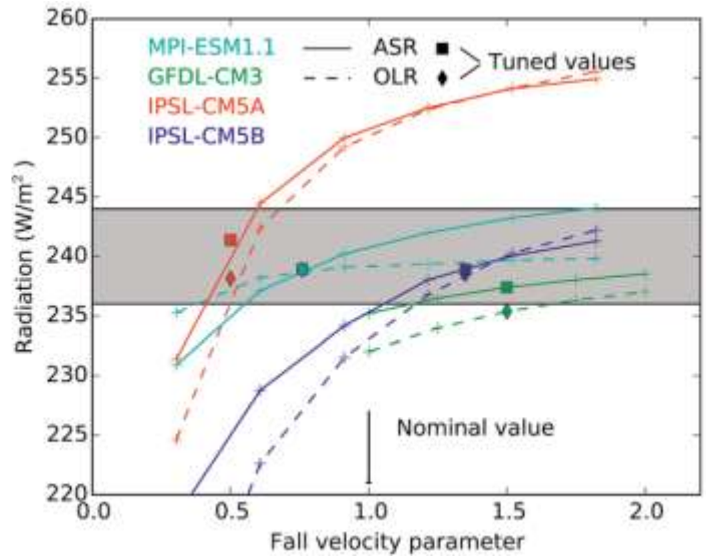
Hourdin et al., BAMS, 2017

(this has relevance to solving OH issues in CTMs)

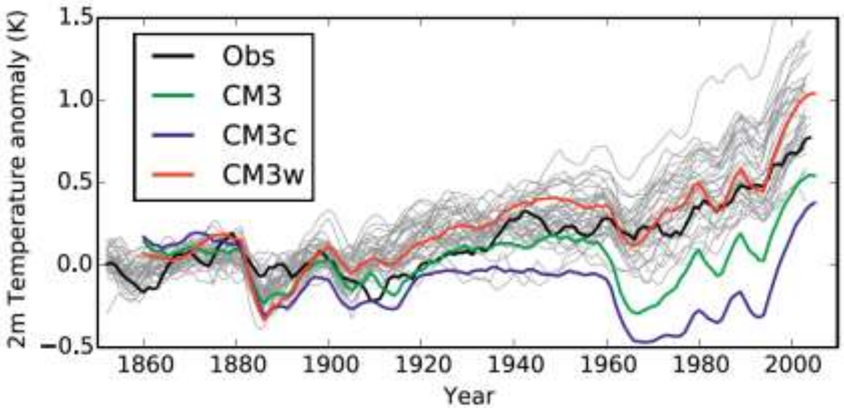
We survey the rationale and diversity of approaches for tuning, a fundamental aspect of climate modeling, which should be more systematically documented and taken into account in multimodel analysis.



Example of tuning approach for the ECHAM model (after Mauritsen et al. 2012). The figure illustrates the major uncertainty in climate-related stratiform liquid and ice clouds and shallow and deep convective clouds. The gray curve to the left represents tropospheric temperatures, and the dashed line is the top of the boundary layer. Parameters are (a) convective cloud mass flux above the level of nonbuoyancy, (b) shallow convective cloud lateral entrainment rate, (c) deep convective cloud lateral entrainment rate, (d) convective cloud water conversion rate to rain, (e) liquid cloud homogeneity, (f) liquid cloud water conversion rate to rain, (g) ice cloud homogeneity, and (h) ice particle fall velocity.



Global absorbed shortwave radiation (ASR, full curve) and outgoing radiation (OLR, dashed) at top of atmosphere. The squares and diamonds correspond to default values retained after a tuning phase (for GFDL and IPSL-CM they correspond to the values retained for CMIP5, but because the experiments were redone with recent versions of the same models, the balance is not completely satisfied with the selected values).

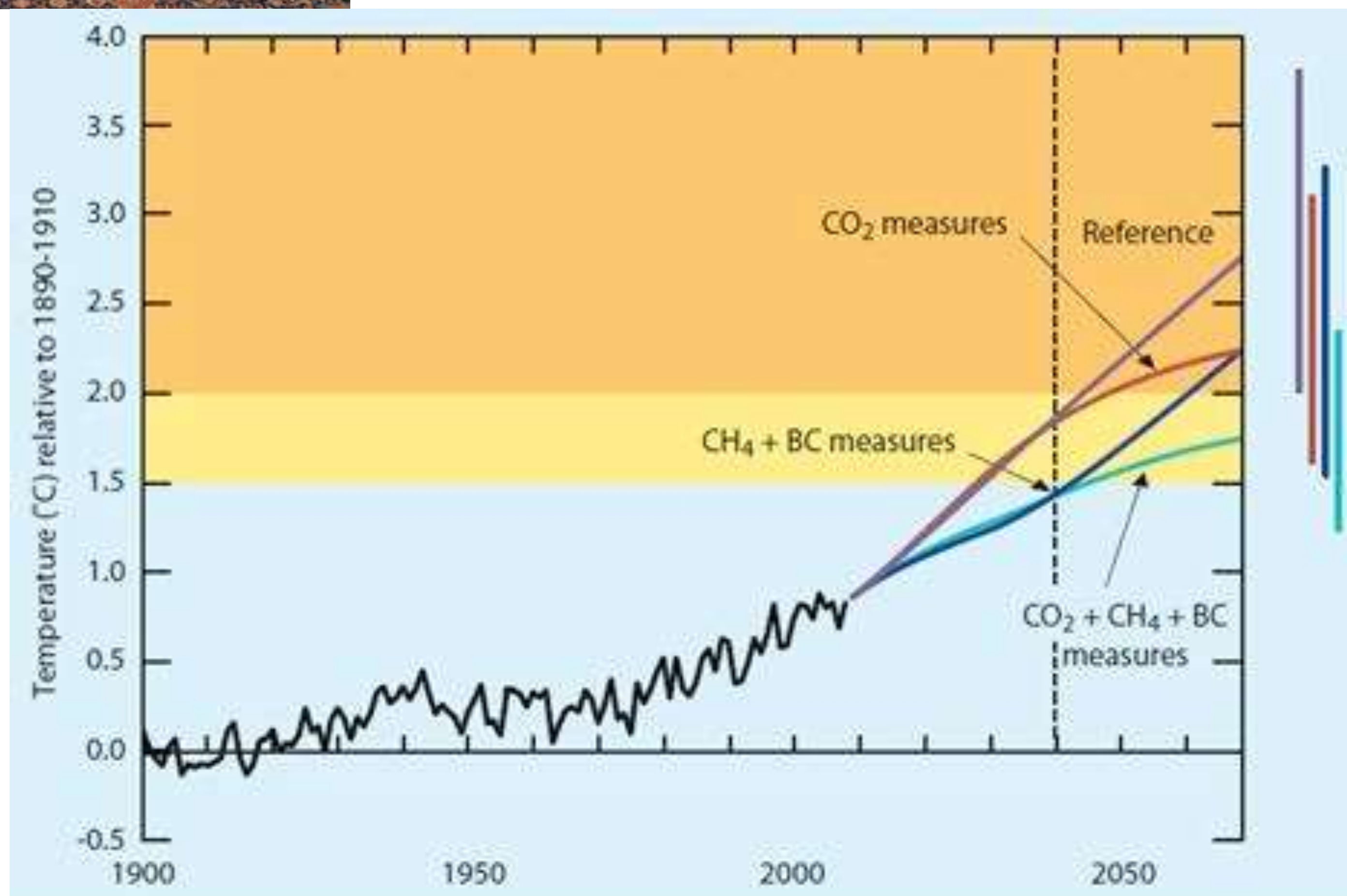


The colored curves correspond to three configurations of the GFDL CM3 model. CM3 denotes the CMIP5 model, while CM3c and CM3w denote alternate configurations with large and smaller, respectively, cooling from cloud aerosol interactions.

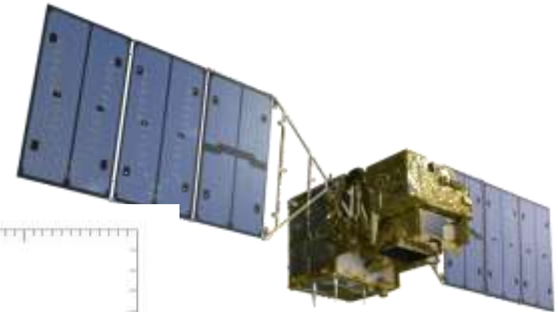
Climate and Clean Air Coalition/CCAC)

Launch of the Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants, Feb 17, 2012. Source: US Department of State

SLCP:
CH4
Tropospheric Ozone
Black Carbon



What is GOSAT?



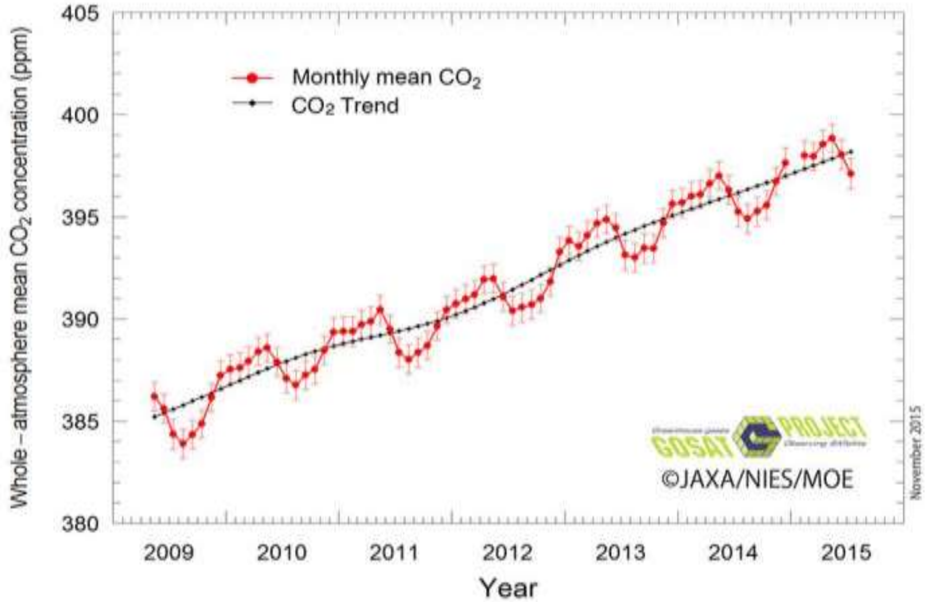
GOSAT(Greenh

– GOSAT is th … -gas-monitoring

– Targets of G

– Onboard se … Spectrometer)

– GOSAT colle … 5.



	2009	2					2015 -
Milestone	* Launch	in operation in space