# Use of multi-tracers simulations for characterizing transport models (TransCom-HIPPO?)

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MEXT

JSPS 独立行政法人 日本学術振興会 Japan Society for the Promotion of Science

Research Institute for Global Change

JAMSTEC

# Introduction

- Uncertainties in transport model impede use and interpretation (inversion) of atmospheric observations

- We believe use of multi-tracers is critical to separate errors associated with surface fluxes and model transport

- HIPPO transects and seasonal measurements provide unique opportunity to characterize transport model properties

# Scheme of GHGs Simulation in ACTM (Patra et al., 2009)

**Model:** CCSR/NIES/FRCGC Atmospheric General Circulation Model (AGCM)

**Meteorology:** ECMWF/NCEP/JMA for the period 1980 – 2011 is nuddged at relaxation time of 1-5 day for U, V, and T

**Gases:** $CO_2$, $CH_3CCl_3$, $CH_4$, CFC-12, $N_2O$, $SF_6$, $^{222}Rn$

**Tracers:**

1. **CO2a: CASA biosphere + Takahashi Ocean + Fossil Fuel**
2. **CO2b: TransCom inversions + Fossil Fuel**
3. **CO2c: HiRes (TDI-64/ACTM) cyclostationary + Fossil Fuel**
4. **CO2d: TDI-64/ACTM + TDI-64/CTME IAV + Fossil Fuel**

5. **$CH_4$: EDGAR Anthropogenic + GISS/VISIT Natural (simple OH chemistry, $O^1D$, Cl)**
6. **$CH_3CCl_3$: McCulloch/Krol (OH, $O^1D$ chemistry; Photolysis, oceanic sink)**

7. **$N_2O$: EDGAR terrestrial + Ocean model ($O^1D$, Photolysis)**
8. **CFC-12: EDGAR-86 + AFEAS modified for trends ($O^1D$, Photolysis)**

9. **$SF_6$: EDGAR + Univ. Heidelberg/Levin (for trends)**
10. **Radon: annual mean flux (simple decay)**
11. **Radon: monthly mean flux**

*Members:*

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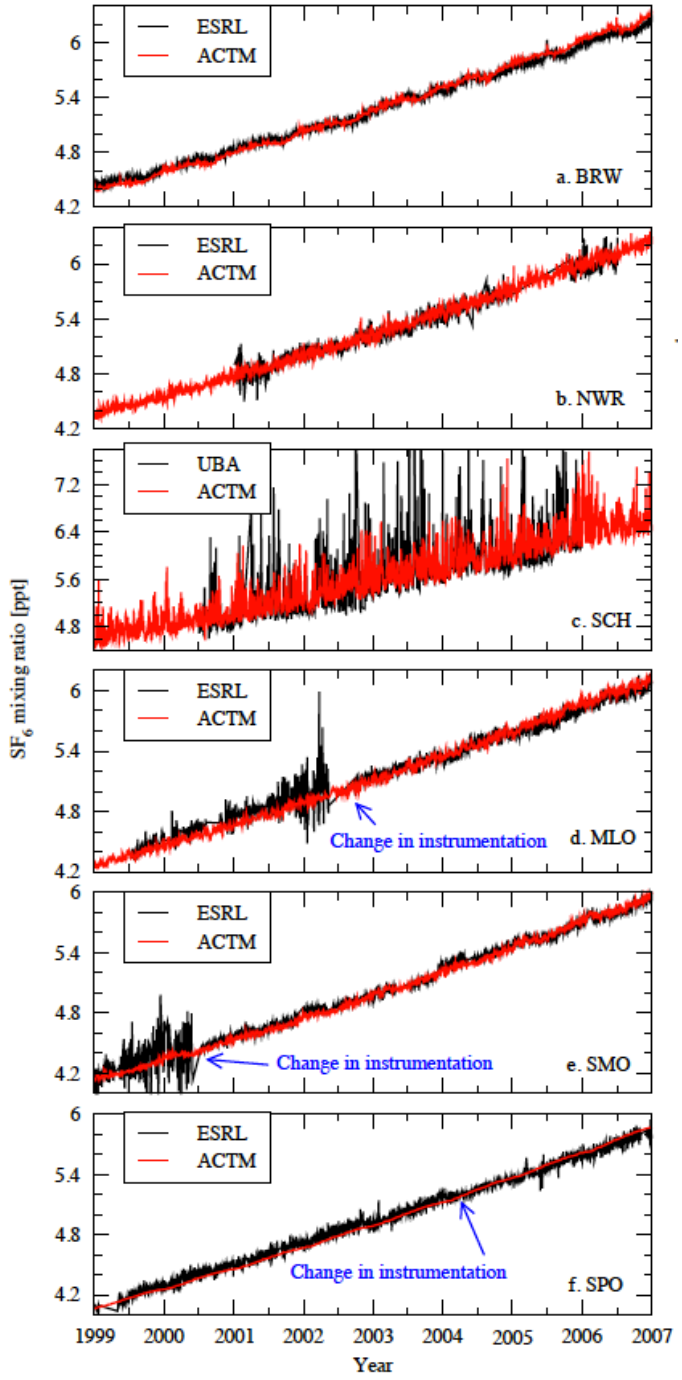
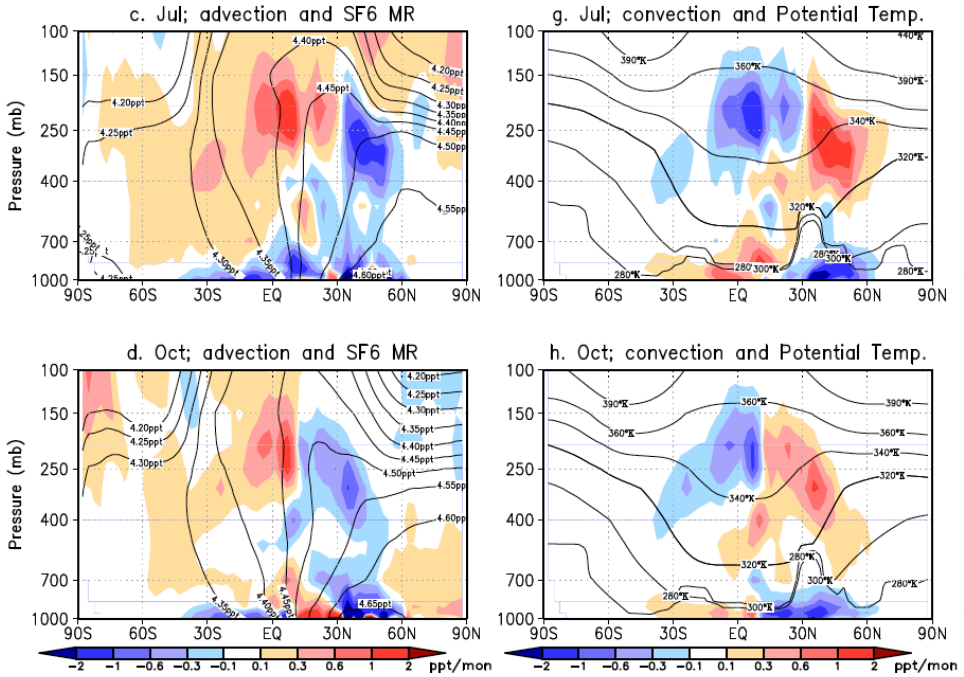
*Updated from Gakujutsu Sousei Meeting*
*CAOS, Tohoku University; 28 Jun 2006*

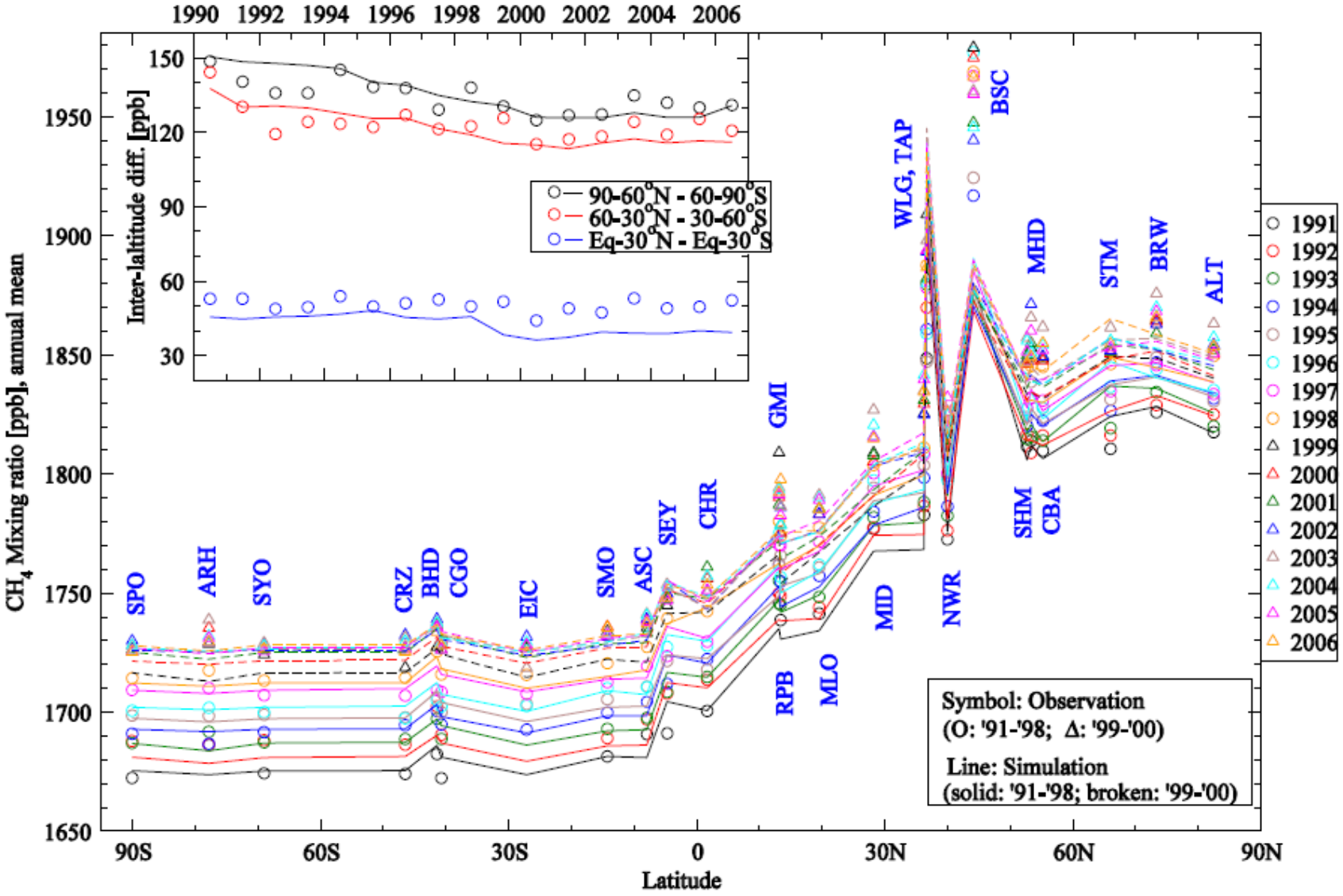
# Atmospheric transport of greenhouse gases (GHGs) in the CCSR/NIES/FRCGC AGCM-based Chemistry Transport Model **(ACTM)**




Patra et al., ACP, 2009

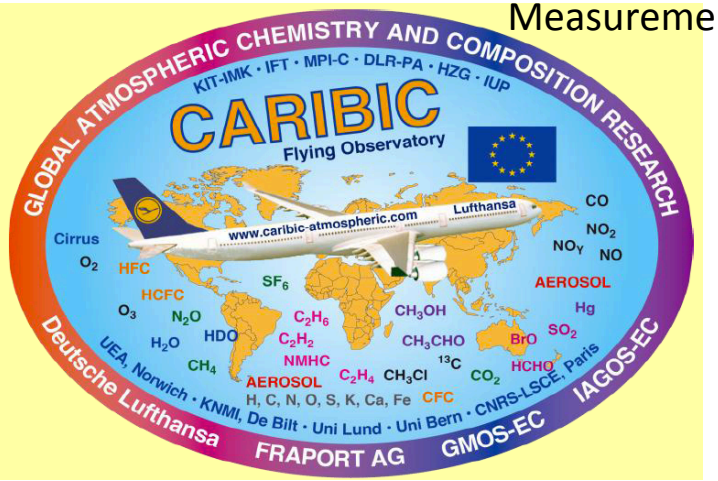
# ACTM simulations of $CH_4$ and $CH_3CCl_3$



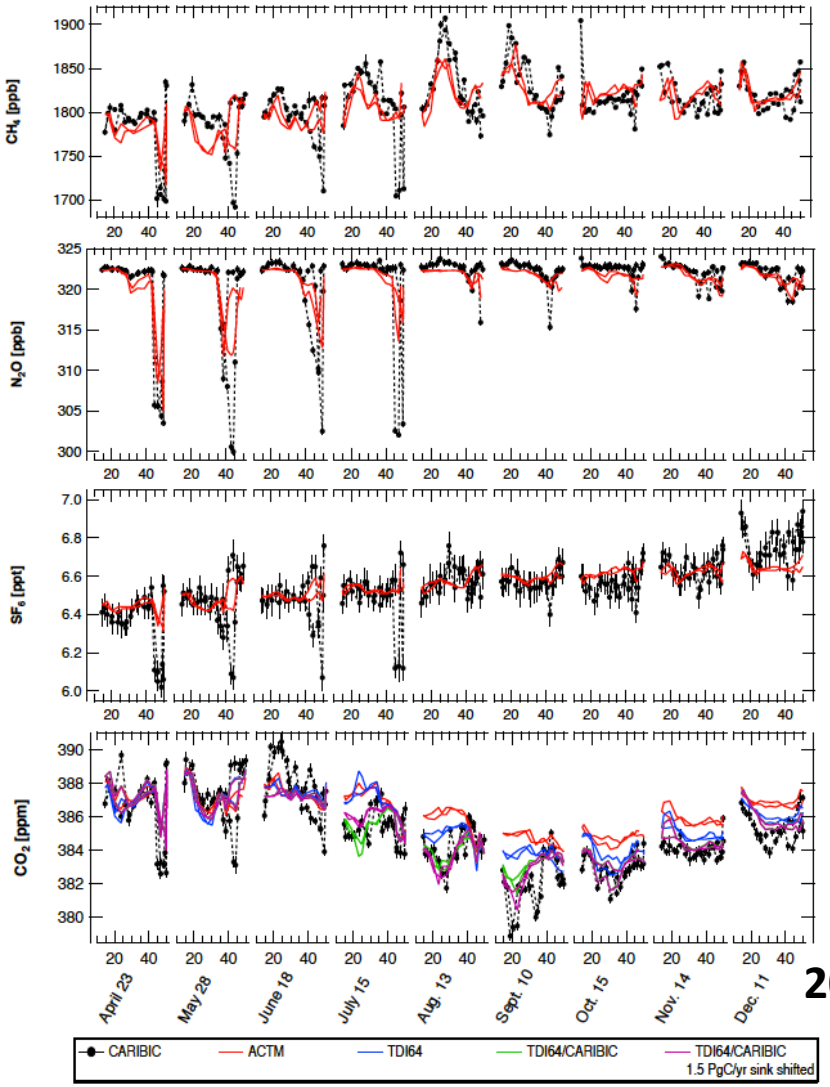

Patra et al., JMSJ, 2009

# Carbon balance of South Asia constrained by passenger aircraft $CO_2$ measurements

(Patra et al., ACP, 2011)

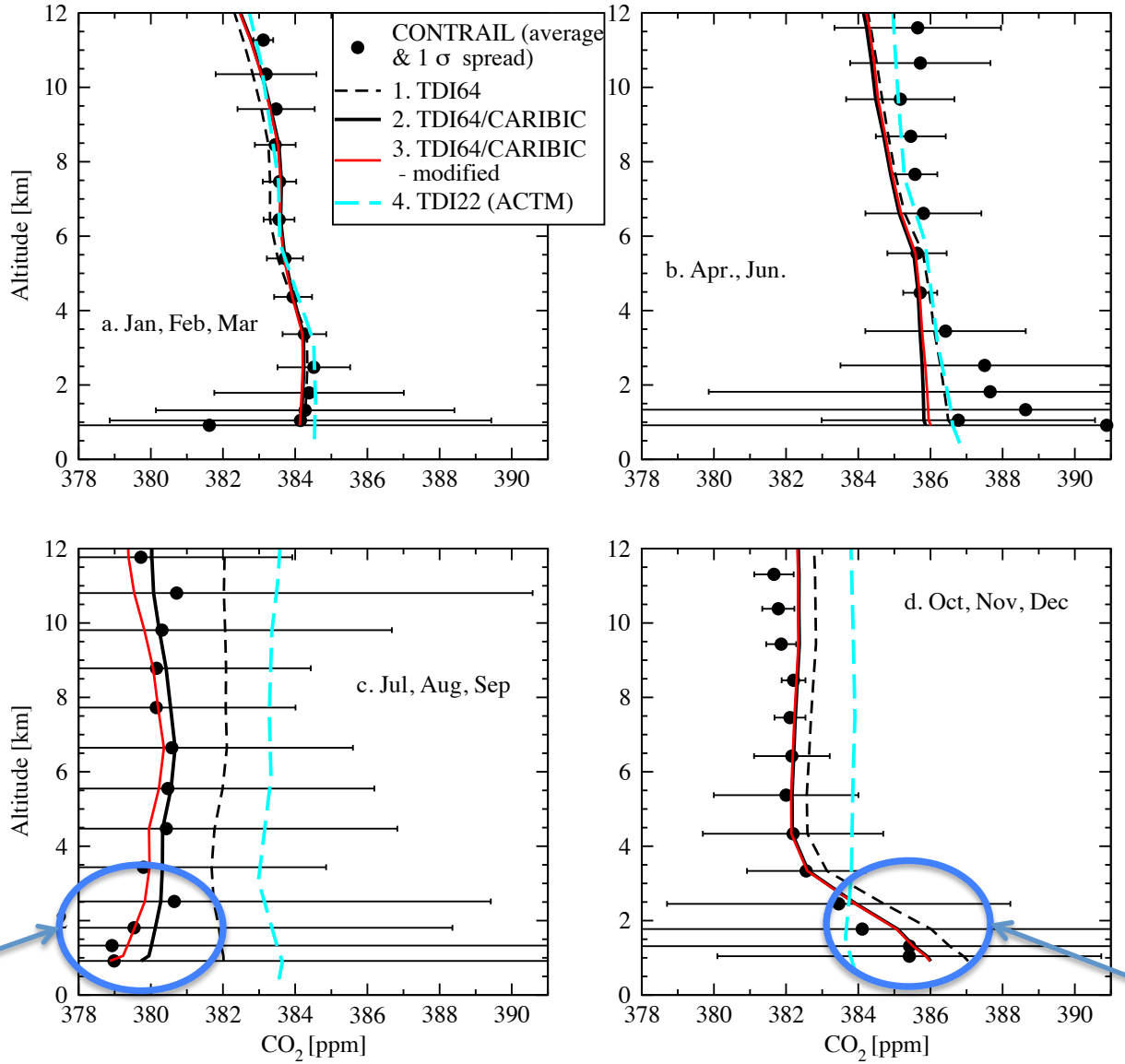



Measurements between Frankfurt, Germany and Chennai, India




CONTRAIL for near-global coverage

# CONTRAIL and ACTM/CARIBIC $CO_2$ over Delhi, India: Role of fluxes on vertical profile simulation

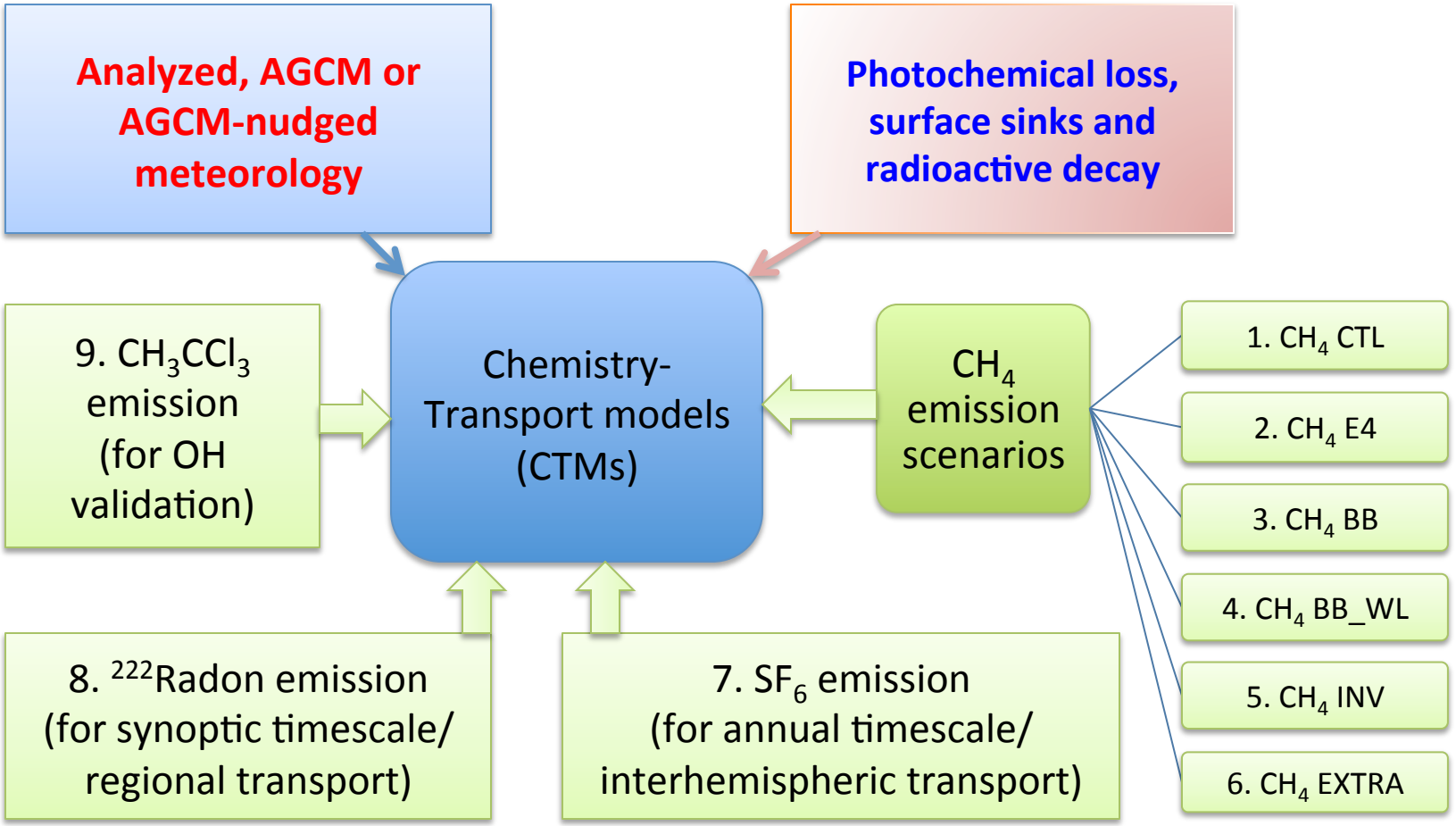



2007

Strong $CO_2$ uptake

Strong $CO_2$ release

# TransCom $CH_4$ : linking chemistry, transport & emission




Patra et al., ACP, 12813ff, 2011

# Participating transport models and model variants in TransCom-$CH_4$ intercomparison (1990-2007)

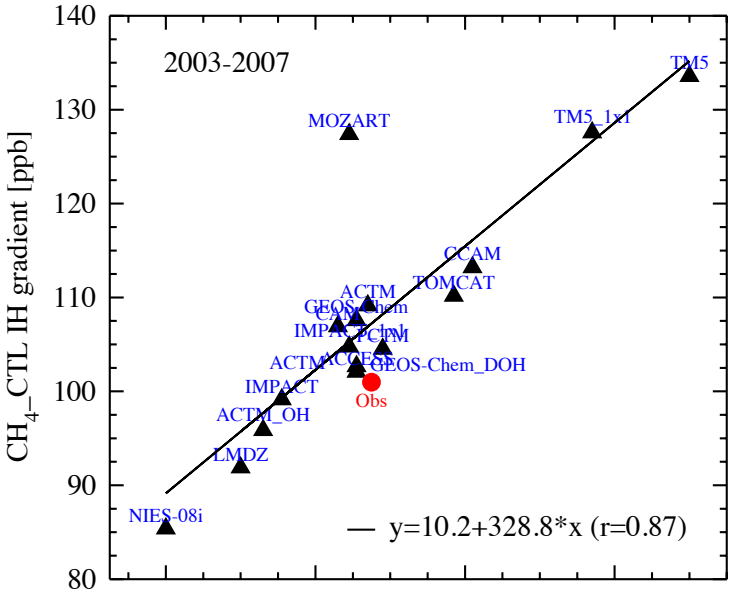
| Sl. No. | Model name[a] | Institution[b] | Resolution | | Meteorology[e] |
|---|---|---|---|---|---|
| | | | Horizontal[c] | Vertical[d] | |
| 1 | **ACCESS** | CSIRO | $3.75 \times 2.5°$ | 38 | AGCM; SST |
| 2 | **ACTM** | RIGC | $\sim 2.8 \times 2.8°$ | $67\sigma$ | NCEP2; U, V, T; SST |
| 2a | ***ACTM_OH***[$] | RIGC | $\sim 2.8 \times 2.8°$ | $67\sigma$ | NCEP2; U, V, T; SST |
| 3 | CAM | CU | $2.5 \times \sim 1.9°$ | $28\sigma$ | NCEP/NCAR |
| 4 | **CCAM** | CSIRO | $\sim 220$ km | $18\sigma$ | NCEP; U, V; SST |
| 5 | GEOS-Chem | UoE | $2.5 \times 2.0°$ | $30/47\eta$ | NASA/GSFC/GEOS4/5 |
| 5a | *GEOS-Chem_DOH* | UoE | $2.5 \times 2.0°$ | $30/47\eta$ | NASA/GSFC/GEOS4/5 |
| 6 | IMPACT | LLNL | $5.0 \times 4.0°$ | $55\eta$ | NASA/GSFC/GEOS4 |
| 6a | *IMPACT_1 × 1.25* | LLNL | $1.25 \times 1.0°$ | $55\eta$ | NASA/GSFC/GEOS4 |
| 7 | **LMDZ** | LSCE | $3.75 \times 2.5°$ | $19\eta$ | ECMWF; U, V, T; SST |
| 8 | MOZART | MIT | $\sim 1.8 \times 1.8°$ | $28\sigma$ | NCEP/NCAR |
| 9 | NIES08i | NIES | $2.5 \times 2.5°$ | $32\sigma$-$\theta$ | JCDAS, ERA-interim-PBL |
| 10 | PCTM | GSFC | $1.25 \times 1.0°$ | $58\eta$ | NASA/GSFC/GEOS5 |
| 11 | TM5 | SRON | $6.0 \times 4.0°$ | $25\eta$ | ECMWF, ERA-interim |
| 11a | *$TM_5$_1 × 1* | SRON | $1.0 \times 1.0°$ | $25\eta$ | ECMWF, ERA-interim |
| 12 | TOMCAT | UoL | $\sim 2.8 \times 2.8°$ | $60\eta$ | ECMWF, ERA-40/interim |

# List of 8 surface sites used in TransCom-$CH_4$ analysis

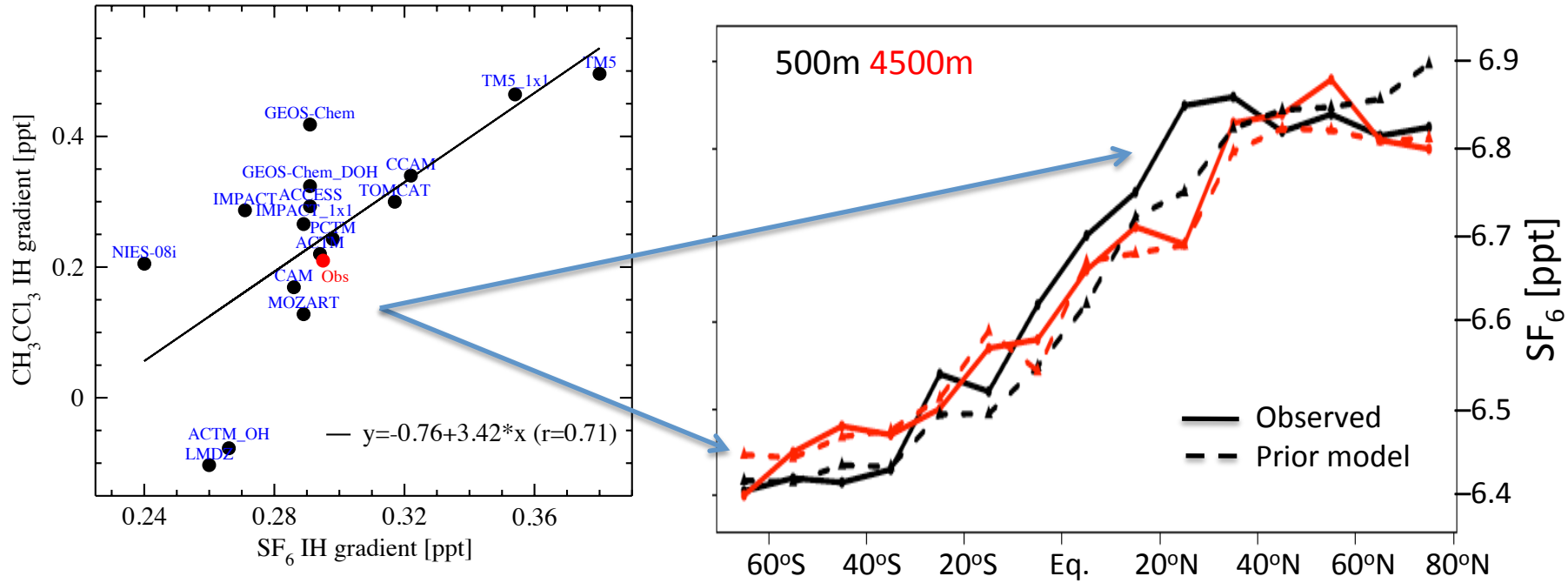
| Station name & location | Data network & managing institution |
|---|---|
| ALT, Alert, Canada;<br>62°W, 82°N, 210m | NOAA: Global Monitoring Division, ESRL<br>(Edward Dlugokencky; James Elkins) |
| BRW, Point Barrow, USA;<br>157°W, 71°N, 11m | NOAA: Global Monitoring Division, ESRL<br>(Edward Dlugokencky; James Elkins) |
| MHD, Mace Head, Ireland;<br>10°W, 53°N, 25m | AGAGE: University of Bristol<br>(Simon O'Doherty; Peter Simmonds) |
| MLO, Mauna Loa, Hawaii, USA;<br>156°W, 20°N, 3397m | NOAA: Global Monitoring Division, ESRL<br>(Edward Dlugokencky; James Elkins) |
| RPB, Ragged Point, Barbados;<br>59°W, 13°N, 45m | AGAGE: University of California, San Diego (Ray Weiss) |
| SMO, Samoa, USA;<br>171°W, 14°S, 42m | AGAGE: University of California, San Diego (Ray Weiss) |
| CGO, Cape Grim, Australia;<br>145°E, 41°S, 94m | AGAGE: Commonwealth Scientific and Industrial Research Organization<br>(Paul Fraser, Paul Steele; Paul Krummel) |
| SPO, South Pole, Antarctica;<br>25°W, 90°S, 2810m | NOAA: Global Monitoring Division, ESRL<br>(Edward Dlugokencky; James Elkins) |

# Inter-Hemispheric (IH) gradient in transport models

TransCom-$CH_4$ (Patra et al., ACP, 2011)

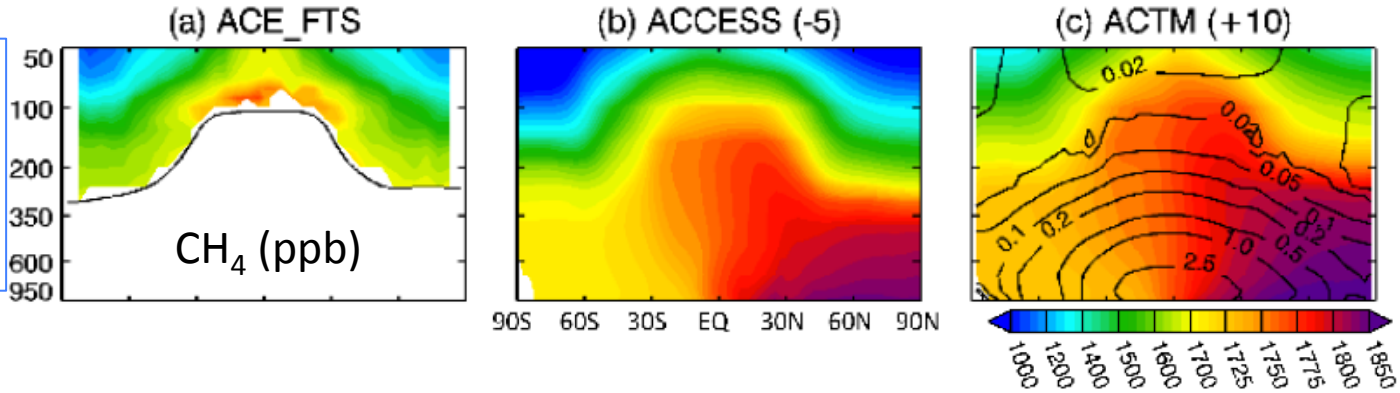



HIPPO (Kort et al., GRL, 2011)



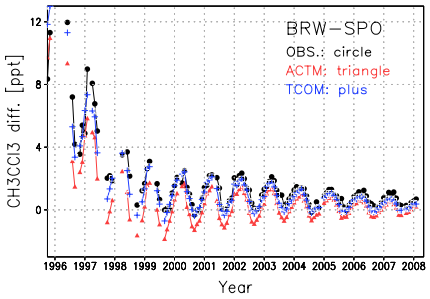
# TransCom-HIPPO intercomparison expectations

1. Never been able to validate the tropospheric cross-sections




2. Multiple species – our best bet to disentangle flux and transport model errors in forward simulations

3. OH in two hemispheres : (critical for CO, $NO_x$, $SO_x$ inversions)




TCOM OH : NH/SH = 0.99 ($\sigma_{press}$=1.0-0.1)

ACTM OH : NH/SH = 1.32

4. Others :

# Possible Target species of TransCom-HIPPO

- Carbon cycle science:
  - $CO_2$ (modelers choose their preferred fluxes – too many options to choose from; inversion fluxes should be without HIPPO data)
  - $O_2/N_2$ (flux: SIO/Keeling makes one set)
  - OCS (flux: UEA/Suntharalingam & ESRL) **(wish list)**

- Atmospheric chemistry and climate
  - $CH_4$ (flux: RIGC/Patra makes two sets; prescribed chemistry)
  - $H_2$ (flux: RIGC & ESRL; prescribed chemistry)
  - CO (flux: WuR/Krol & GEOS-Chem; prescribed chemistry)

- $N_2O$ (flux: RIGC; prescribed chemistry)

- Halocarbons
  - $CH_3CCl_3$ (flux: WuR/Krol makes one set; prescribed chemistry)
  - CFC-12 and others (flux: RIGC & ESRL make one set; prescribed chemistry)
  - HCFC-22 and others (flux: RIGC & ESRL make one set; prescribed chemistry)

- Model transport validation
  - $SF_6$ (flux: RIGC & ESRL makes one set; no chemistry)
  - $^{222}$Radon (flux: available standard; radioactive decay time)

# Period of simulation

- 1995 – 2011
    - 1995-2004 spin-up for establishing stratosphere-troposphere transport and photo-chemical equilibrium for most species
    - 2009-2011 analysis
- Other?

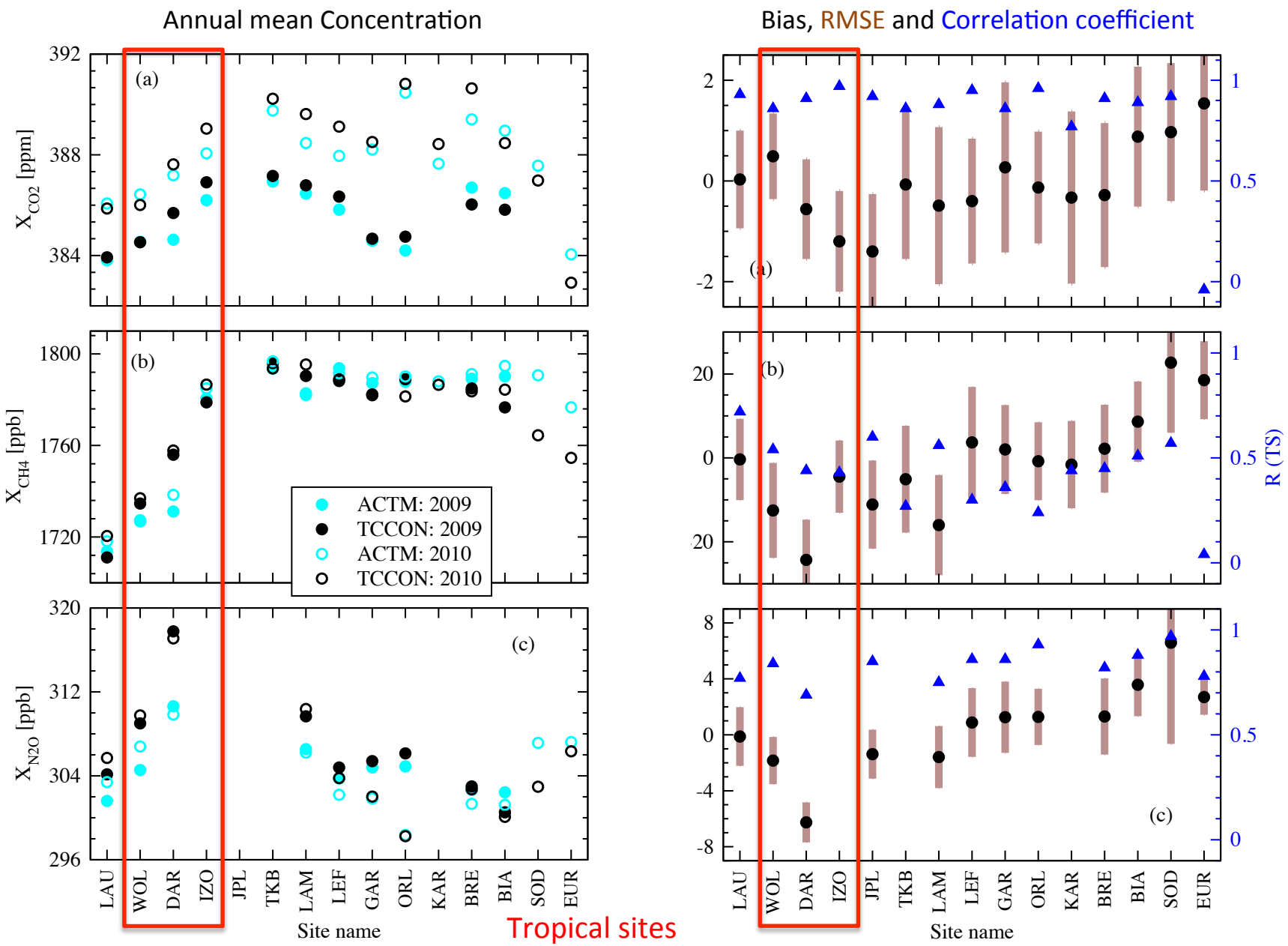
# Model output

- Monthly-mean/daily-noon on constant pressure surfaces: 2005-2011 (standard: 1000-10 mb)
- 3-hourly output for the 5 HIPPO months (standard pressure: 1000-100 mb)
- Profile sampling along the HIPPO tracks (fortran program will be provided)
- Hourly model output at a selected (100 odd) surface stations
- 3D file format is NetCDF and sampling location as ASCII?
- Other issues?

Some additional thoughts

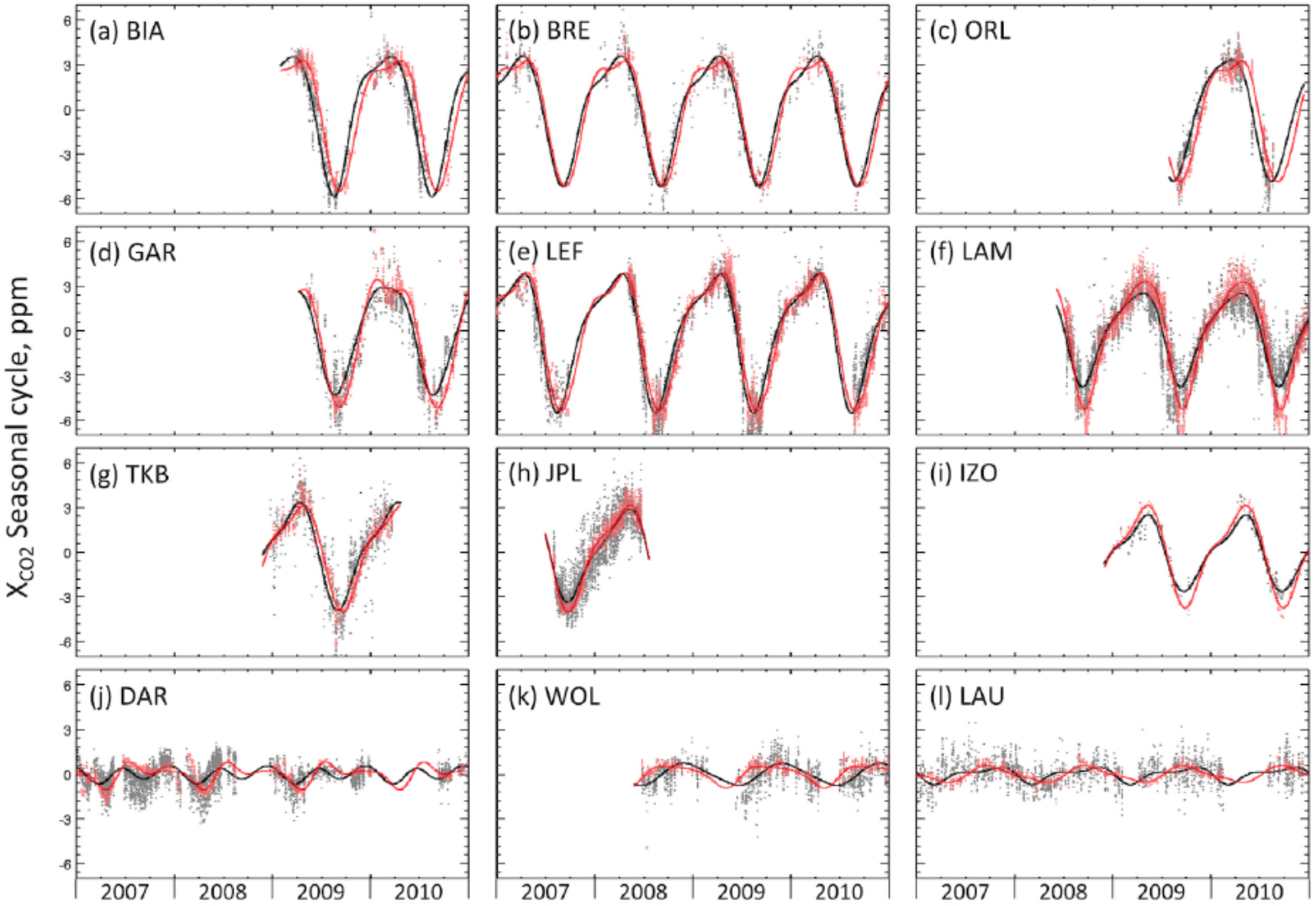
# APPLICATION OF HIPPO AND MODEL FOR INTERPRETING REMOTELY SENSED TOTAL COLUMNS

# Comparison of ACTM simulations with TCCOM



# TCCON and ACTM seasonal cycles

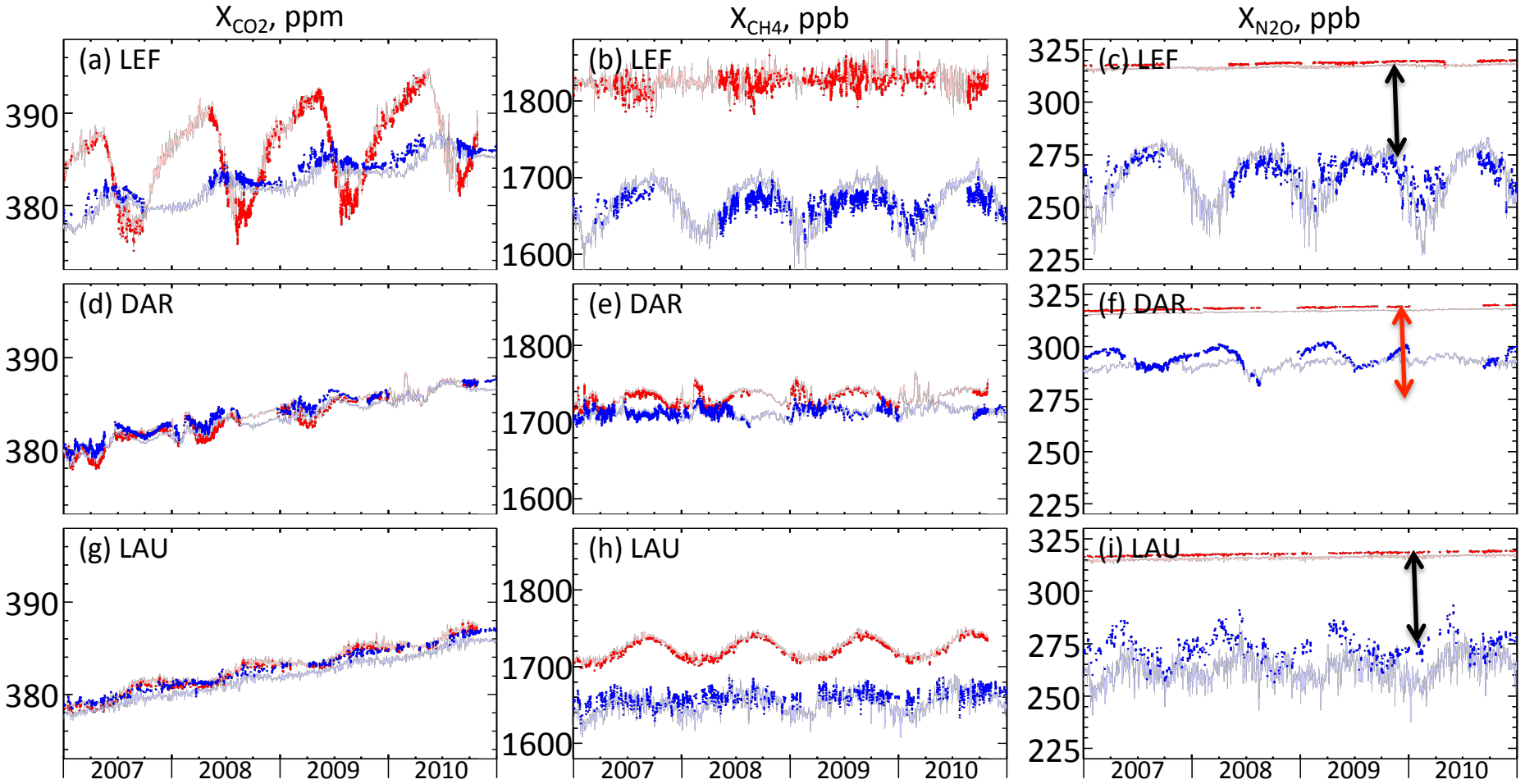
(amplitudes overestimated at d. GAR, f. LAM, i. IZO)




Saito et al., ACPD, 2012

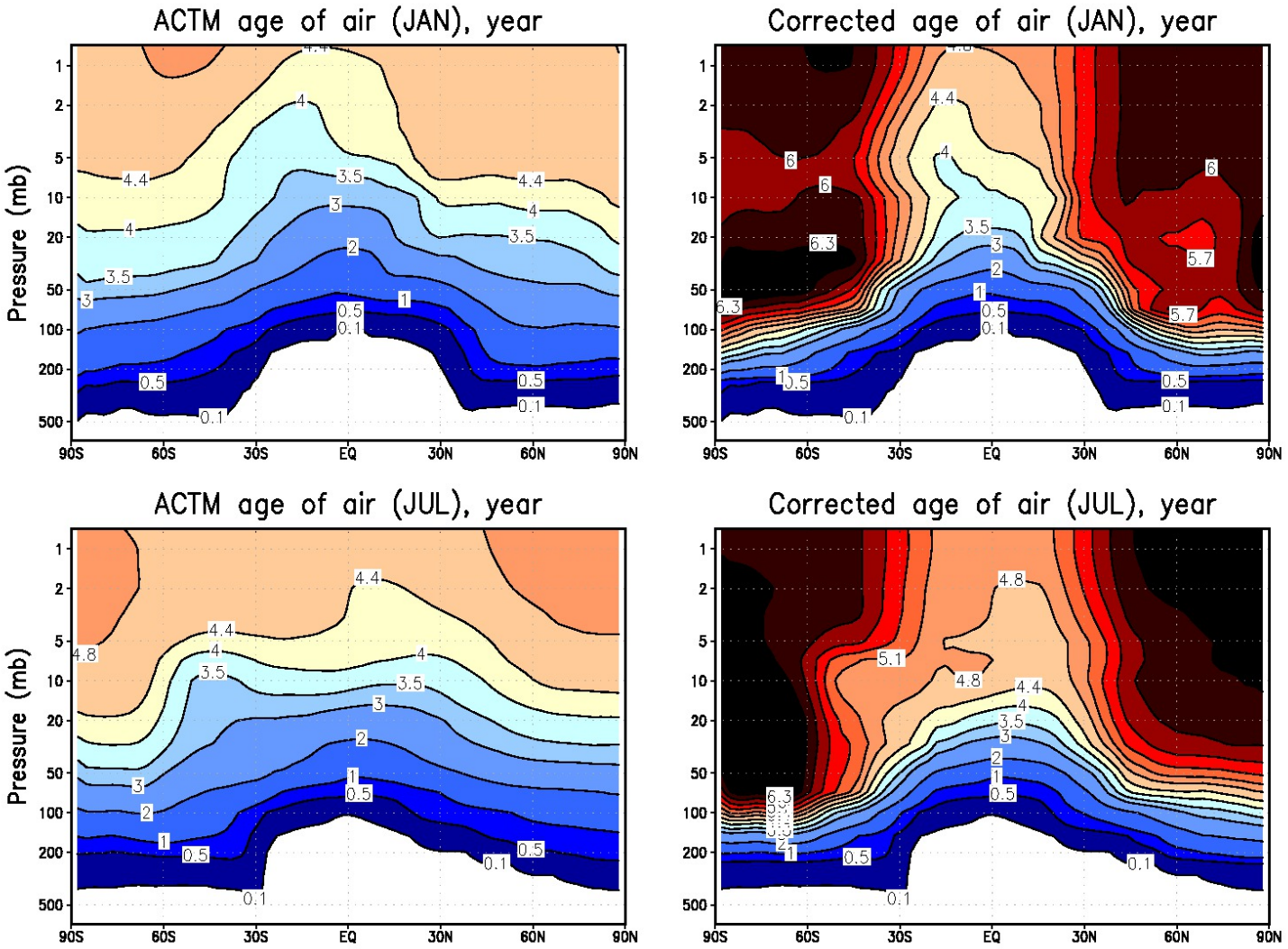
# What's in the total column values?

Red : troposphere  Blue: stratosphere



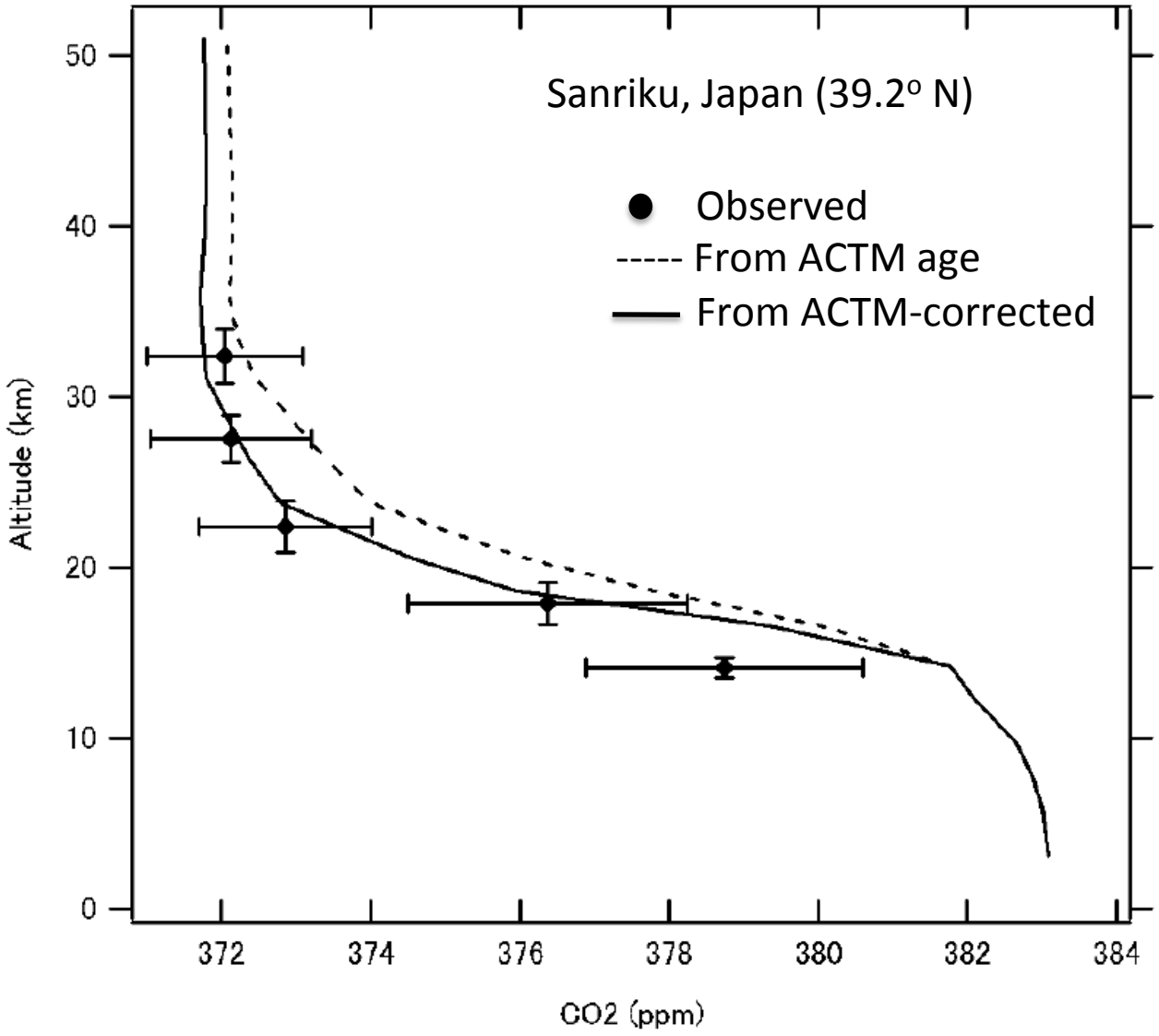

Saito et al., ACPD, 2012

# Why are the troposphere and stratosphere so different?




Harnisch et al., GRL, 1996; Patra et al., JGR, 1997; Patra et al., ACP, 2009; Saito et al., JGR, 2011

# Reconstruction of tracer ($CO_2$) profiles from 'age of air'




Miyamoto et al., in prep.

Further validation:

1. Use Andrews et al. for the lower stratosphere

2. Additional data from balloon profiles from other latitudes

3. Extension to other species, $CH_4$, $N_2O$…