Protocol for TransCom CH_4 intercomparison

Prabir Patra[1], Sander Houweling[2], Maarten Krol[2,3], Philippe Bousquet[4], Lori Bruhwiler[5], Daniel Jacob[6]

1. Research Institute for Global Change/JAMSTEC, Yokohama, Japan
(e-mail: prabir@jamstec.go.jp)
2. Netherlands Institute for Space Research (SRON), Utrecht, The Netherlands
(e-mail: s.houweling@sron.nl)
3. Wageningen University, The Netherlands (e-mail: maarten.krol@wur.nl)
4. Universite de Versailles Saint Quentin en Yvelines (UVSQ), GIF sur YVETTE, France
(e-mail: bousquet@lsce.ipsl.fr)
5. NOAA Earth System Research Laboratory, Boulder, Colorado, USA
(e-mail: lori.bruhwiler@noaa.gov)
6. Harvard University, Cambridge, Massachusetts, USA (e-mail: djacob@fas.harvard.edu)

Version 6.2

06 November 2009

1. Aim of experiment

Simulation of the variability of atmospheric methane (CH_4) depends on the spatio-temporal variations in fluxes, model transport and destruction due to OH, Cl and O^1D chemistry. Most model simulations so far have addressed some of these issues in a single transport modeling framework. CH_4 measurements are now being conducted at a greater number of sites as well as at hourly or daily time intervals in recent years. The satellite data from SCHIAMACHY, AIRS, and GOSAT may also be used for comparison. There have also been significant developments in our understanding of CH_4 flux distributions in the past few years through both forward and inverse modeling. However, further improvements (and statistical confidence) in inverse modeling results would depend on quantification of a priori errors in forward modeling.

Unlike the past TransCom activities which focused on CO_2, introduction of atmospheric chemistry will be required in a CH_4 intercomparison. Our main aim here will be to quantify the role of transport, flux distribution and chemical loss (and resultant North-South CH_4 gradient) in simulating the seasonal cycle (SC), synoptic variations (SV) and the diurnal cycle (DC) in CH_4 mixing ratio. This intercomparison is also likely to supplement the recently concluded TransCom continuous experiment for CO_2, since the flux distribution (mainly emissions) and the chemical removal by OH (mainly in the tropics) lead to different behaviour of CH_4 compared to CO_2.

2. Simulations required

In view of the recent developments, a multi-transport model simulation of CH_4 is proposed, using the fluxes as listed in Table 1, for the 9 tracers listed in Table 2. Only one OH field is supplied here, which should be common for all forward simulations (important for quantifying model transport differences). We also encourage the modelers to submit another simulation using their preferred OH field that is possibly adjusted to match CH_4 growth rate for their forward model or optimized with respect to CH_3CCl_3 (MCF; Methyl Chloroform). MCF will also be simulated as an additional tracer, and will be used as tests for the OH-fields as provided here or the modeler's own as well as to improve our understanding of the MCF emission/loss cycle.

The transport models are expected to run using analyzed meteorology for the period of 01 Jan 1990 to 31 Dec 2007, after a spin-up of 2-years using 1990 or 1988-1989 meteorology. If analysed meteorology is not possible, GCM winds may be used, though this will limit some aspects of the analysis for those models. The simulations will be used for analysis of different aspects of the spatio-temporal CH_4 variability in comparison with a variety of observations. Nevertheless, if the period of simulation is too long for some modelers, they are allowed to submit their results for a shorter time period, which is at their discretion, after a spin-up of designated two years using meteorology corresponding to their start year of the simulation. The spin-up period has been reduced to 2 years, but to meet the goal of realistic stratospheric-tropospheric exchange (STE) rate a 2-dimensional CH_4 field (provided here) should be used to initialize the model spin-up run.

Model output is requested at a number of sites at hourly time interval for the full period of simulation, and gridded output at monthly intervals at the model horizontal resolution but preferably at standard pressure levels. Afternoon averages (12:00-15:00 Local Time) at daily intervals are requested for the period 2001-2007. This gridded output at daily intervals will be primarily used for comparing the model simulations with SCHIAMACHY and AIRS observations.

Table 1: List of CH_4 emissions and sinks categories (IAV: inter-annually varying; CYC: one seasonal cycle repeating every year) and their suppliers. Details regarding OH fields, Cl & O^1D loss parameterization and CH_4 initial values are also provided.

PARAMETERS	DESCRIPTION	TIME RESOLUTION
1. CH_4 Fluxes* (Appendix 1)		
Anthropogenic emission (IAV ANT)	Based on EDGAR 3.2 / FT categories (Olivier et al.)	Annual means; IAV (inter-/extra-polated using 1990, 1995, 2000 emission maps)
Anthropogenic emission (IAV ANT E4)	Based on EDGAR 4.0 categories (van Aardenne et al.)	Annual means; IAV (used 2005 for 2006-2008); Trends in Rice emission is used to scale REAS rice
Natural emission (CYC NAT)	GISS inventory (Fung et al.), REAS rice (Yan et al.), Ocean and Mud Volcano	Monthly-mean; CYC
Wetland emission (IAV WL)	ORCHIDEE model based (Ringeval et al.)	Monthly-mean; IAV for 1994-2000 (CYC for 1988-1993 & 2001-2008)
Wetland emission; EXTRA (IAV WLe)	VISIT model simulated Wetland and Rice (Ito et al.)	Monthly-mean; IAV 1988-2008
Biomass Burning emission (IAV BB)	GFED version 2; Satellite products based (van der Werf et al.)	Monthly-mean; IAV for 1996-2008 (CYC for 1988-1996)
Inversion flux (IAV INV)	IPSL optimized flux (Bousquet et al.)	Monthly-mean; IAV for 1988-2005 (CYC for 2006-2008)
2. Tropospheric Loss (OH field)		
Optimized OH for global CH_3CCl_3 concentration	Scaled from Spivakovsky et al. (2000) by M. Krol	Monthly-mean; CYC (file: ohfield_mcfcal.nc)
Modeler's Choice (*Additional run*)	Model specific OH field – optimized CH_4 growth rate	CYC or IAV
3. Stratospheric Loss by Cl, O^1D		
Loss rates due to Cl & O^1D	From 2-D stratospheric chemistry model (Cambridge model)	Monthly-mean, CYC (file: ch4loss_strat_cl+o1d.nc)
Modeler's choice (*Additional run*)	For those using GCMs (*Modeler's are encouraged to share their radical fields, if possible, with others*)	3D, IAV
4. CH_4 Soil Sink (Appendix 2)		
Soil Sink (SOIL)	IPSL optimized (Bousquet et al.)	Monthly-mean climatology (file: flux_CH4_SOIL_SINK.nc)
5. CH_4 Initial Condition (Details in Section 4)		
CH_4 mixing ratio	Based on tropospheric flask measurements near surface and HALOE climatology	2D (latitude-pressure), 01 January 1988 (file: ch4_initial.nc)

Table 2: List of 6 CH_4 and 3 supplementary tracers to be simulated for TransCom-CH_4 intercomparison project. A combination of CH_4 emissions is provided for use in CH_4 simulations based on the above flux components (Table 1) so that CH_4 losses are modeled properly (SOIL sink, and OH, Cl & O^1D reactions).

PARAMETERS	DESCRIPTION	TIME RESOLUTION
CH_4 tracers (Appendix 1 for emission total)		
1. CH4_CTL	CYC NAT + IAV ANT (CYC BB & CYC WL)	Monthly means; IAV (file: flux_CH4_CTL.nc)
2. CH4_CTL_E4	CYC NAT + IAV ANT E4 from EDGAR4.0 @JRC	Annual means; IAV (file: flux_CH4_CTL_E4.nc)
3. CH4_BB	CH4_CTL – 0.35 CYC BB + IAV BB	Monthly means; IAV (file: flux_CH4_BB.nc)
4. CH4_WL_BB	CH4_BB – CYC WL + 0.76 IAV WL	Monthly means; IAV (file: flux_CH4_WL_BB.nc)
5. CH4_INV	as in Table 1	Monthly means; IAV (file: flux_CH4_INV.nc)
6. CH4_EXTRA*	CH4_BB – CYC WL– Rice + WLe IAV (0.69 Wetland + 0.895 Rice)	Monthly means; IAV (file: flux_CH4_EXTRA.nc)
Supplementary Tracers (Appendix 3, 4 & 5)		
7. SF_6	EDGAR 4.0 (@JRC); Global totals corrected as per Levin et al.	Annual means, IAV (Appendix 3) (file: flux_SF6IL.nc)
8. Radon	As in TransCom continuous (following Jacob et al.)	Annual mean (Appendix 4)
9. MCF (CH_3CCl_3)	EDGAR3.2 with McCulloch trends	Annual means; IAV (Appndx 5) (file: flux_MCF_.nc)
Stratospheric loss rates due to photolysis	From ACTM model run (Patra et al.)	Monthly means; CYC (file: mcf_strat_J.nc)
Oceanic sink	Prepared by M. Krol	Monthly means; CYC (file: mcf_loss_ocn.nc)

*this tracer is called EXTRA because the VISIT terrestrial ecosystem model fluxes are still under evaluations, but included here since no other bottom-up wetland emission is available with IAV for the full simulation period.

Note that CH4_CTL tracer is based on our present state-of-the-art bottom-up emission inventories. The fluxes with IAV are added to provide an extra dimension to the CH4_CTL without disturbing the global totals aggregated over the period of 1990-2005, which is important for simulating the CH_4 growth rate close to the observations. For example, while adding IAV BB component, only 0.38 CYC BB is removed, since IAV BB is about 35% the amount of biomass burning emission in CH4_CTL. On the other hand, because IAV WL fluxes are greater than CYC WL emission in CH4_CYC, the IAV WL emissions have been scaled down (Table 2).

3. Input files and sample code

Much of this section is similar to Law et al. (2006), the TransCom Continuous experimental protocol and we will abide by that for the convenience of modelers who are common to both experiments.

Input files and sample codes can be downloaded using ftp.

ftp fxp.nies.go.jp
Login: transcom-ch4
Password: Rkd(7uf%

The surface flux files are available in the sub-directory 'input_files' in NetCDF format (ASCII or simple binary formatted files are available on request).

```
ftp> cd input_files
ftp> binary
ftp> prompt
ftp> mget *.nc
ftp>cd ../sites_program
ftp> mget *
```

The 'input_files' directory contains all the fluxes (flux_*.nc), OH (ohfield_mcfcal.nc), stratospheric loss (ch4loss_strat_cl+o1d.nc), 2-D CH_4 initial values (ch4_initial.nc) as well as 3-D initial values for CH_4, SF_6 and MCF (actm_*init1988.nc), and some ACTM fields used in the example global loss calculation program.

The 'sites_program' directory contains site lists ('site.list.all' & 'site.list.profile' ASCII files), sample codes for writing output files in a common NetCDF format. The code is written in Fortran 90 and requires modellers to add sections as applicable for their model.

3.1 File format

All input files are in NetCDF format. The spatial resolution is 1ºx1º for all fluxes and OH fields. The latitudes and longitudes are listed in the NetCDF file and represent the mid-point of the grid-cell for which the flux is applicable. Longitudes are ordered from west to east starting from the dateline and latitudes from south to north. The temporal resolution (monthly or annual mean) varies between the fluxes. Use the given fields as mid-interval values and then 'connect-the-dots' by linear interpolation. This will cause your monthly totals to deviate from the mid-month values in this document, but not by much. For fields used every year, glue a December to the start of the series and a January to the end for interpolation of 1-15 January and 15-31 December.

In general we recommend linear interpolation of the fluxes in time. However if your model routinely uses a different interpolation you may use your standard model procedure but please indicate what this is in the model information file (see sec 6.7).

3.1.1 Annual fluxes with IAV
SF_6 flux has a different magnitude and spatial distribution for each year. Scale the sources to give linear changes between the global source totals for each year, taking these as applicable to the middle of the year (day 182.5).

3.1.2 Monthly fluxes
CH_4 soil sink have monthly resolution. The fluxes should be taken as applicable for the middle of the month. We suggest to add the soil sink values to the 6 different source combinations of CH_4 tracers as listed in Table 2. If the modellers have other sophisticated tool to incorporate this sink, linear interpolation is recommended between mid-months for each model timestep.).

3.1.3 Monthly fluxes with IAV
All other CH_4 fluxes have monthly resolution and supplied for multiple years. The fluxes should be taken as applicable for the middle of the month. Linear interpolation is recommended between mid-months for each model timestep.

3.1.4 Units
All fluxes are in mol m^{-2} s^{-1}. Positive fluxes indicate tracer going into the atmosphere.

3.2 Regridding
The surface fluxes need to be aggregated to your model grid. Since we will be comparing the model simulations for the 1990-2007, it is important to ensure that the same global flux is input to each model. Therefore as a final step in regridding the fluxes, please rescale all values to give the same integrated global source as given by the 1×1º fluxes. For the annual and monthly sources, the global totals are listed in Appendixes 1-5.

Many models used a fixed land/ocean mask where each grid-cell is defined as either land or ocean. Wherever possible we would like to keep land fluxes within model grid-cells that are defined as land and ocean fluxes within ocean grid-cells.

See Appendix 4 for information on the radon flux.

4. CH_4 and MCF chemistry, and initial values for CH_4, MCF, SF_6 and Radon

The following chemical mechanisms for CH_4 (Eqn. 1-3) and MCF (Eqn. 4-6) loss should be considered in the forward simulations.

1. $CH_4 + OH \rightarrow CH_3 + H_2O$ [$K_{OH} = 2.45\times10^{-12} \exp(-1775/T)$]
2. $CH_4 + O^1D \rightarrow$ Products [$K_{O^1D} = 1.5\times10^{-10}$)]
3. $CH_4 + Cl \rightarrow CH_3 + HCl$ [$K_{Cl} = 7.3\times10^{-12} \exp(-1280/T)$]

4. CH_3CCl_3+OH → Products [K_{OH}= 1.64×10^{-12} exp(-1520/T)]
5. CH_3CCl_3+J (UV) → Products
6. CH_3CCl_3+D_ocn → Oceanic MCF

The temperature-dependent reaction rates (k) are taken from JPL synthesis report (Sander et al., 2006). Note that only OH fields are provided here for online calculation in the model and parameterized loss rates [K_{O^1D}*O^1D+ K_{Cl}*Cl] for Cl & O^1D reactions with CH_4 are provided in a separate file (ch4loss_strat_cl+o1d.nc), which are based on the Cambridge model.

For MCF, the photolysis rates ***J*** due to solar UV radiation (mcf_strat_J.nc) and air number density (actm_density_AIR.nc) are provided from ACTM.
Because the resolution in the stratosphere varies widely between models, it is necessary to scale the stratospheric loss of MCF to a common value. This value is calculated by mass-weighted averaging:

$$J_{av,MCF} = \frac{\sum_{i,j,k} J_{MCF}(i,j,k)M(i,j,k)}{\sum_{i,j,k} M(i,j,k)}$$

Here, M(i,j,k) denotes the mass in gridbox (i,j,k). Modellers should scale their interpolated J_{MCF} field to match the $J_{av,MCF}$ field of the ACTM model (Appendix 6).

Similarly, the annual and global mean rate constant for CH_4 oxidation due to stratospheric Cl and O^1D is 1.01905E-09 s^{-1}.

The monthly deposition velocities (*dep_mcf*; units: m/s) of MCF to ocean surface are also provided (mcf_loss_ocn.nc). This should be applied in the model as:

$$MCF = MCF * EXP(-dep\_mcf * \frac{1}{dz} * dt)$$

where, *dz* = atmospheric lowest layer depth (m), and *dt* = timestep (s).

Due to slow CH_4 & MCF loss rate and vertical transport (age of air ~5 years in the stratosphere), in order to establish a realistic CH_4 & MCF vertical profile in the stratosphere many years of spin up run is required. To avoid such a long spin up, a latitude-pressure distribution file is prepared for use as the initial condition. Since we recommended two years of spin up run prior to the actual simulation starting from 01 January 1990, the initial concentration levels are set at 01 January 1988.

SF_6 initial value may be set uniformly for all model grids at the 1.95 ppt, which corresponds to the NH & SH average in Maiss et al. (1996) during January 1988.

However, modelers are free to use their own longer spinup runs if that is more convenient, compared to using the initial value file, and in that case adjust your CH_4 and SF_6 values at SPO to 1655 ppb and 2.09 ppt, respectively, to match with the observed concentrations for January 1988.

If modelers are not able to run the full simulation period and want to start at a later year, please ask for specific year's initial conditions. Also a set of 3D initial conditions, prepared using ACTM is also made available for 01 Jan 1988 for CH_4, SF_6 and MCF (actm_CH4init1988.nc, actm_SF6init1988.nc, actm_MCFinit1988.nc). Since modelers have to use the MCF photolysis rate as calculated by this model, converting the initial conditions as well from the same model grid (T42 spectral truncations) may be convenient.

Radon initial concentration should be set at 0.0, which will be spun-up quickly due to its half-life of several days.

5. Site lists and pressure levels for 3D output

Two site lists has been provided in the 'transcom-ch4/sites_program' directory; 1. site.list.all and 2. site.list.profile. For the 'all' list, hourly tracer concentration is required for the site location. For the 'profile' list, hourly tracer concentration and meteorological parameters are required as the model output for all levels up to around 10000m. For the 'all' case you are free to choose whether you submit data for the nearest model gridpoint and model level to the site location or whether you interpolate between gridpoints and/or levels. If choosing a model level for mountain sites, the level below the site may be better than the level above the site, based on the results from the CO_2 intercomparison. The lowest model level is usually a poor choice for mountain sites. If the same site is on the 'all' and 'profile' list, please ensure the same horizontal location is used in both cases.
The fifth column of the site list indicates whether the sampled grid-point should be land or ocean. Please check that the surface type of your output gridpoint agrees with the requested surface types. For coastal sites, data should be submitted for both the nearest land gridpoint and the nearest ocean gridpoint. For models with fractional land area in a grid-cell, use 50% as a cut-off as to whether the grid-cell is considered to be ocean or land. Interpolation is not recommended for coastal sites.
The final column in the site list indicates whether the altitude given is meters above mean sea level (masl) indicated by a 0 in the column, or meters above the ground (mag) indicated by a 1. This may help you to determine what model level to sample to best represent the site given your model vertical resolution and topography.

Monthly/daily mean output are requested at the model horizontal resolution for 17 pressure levels (1000, 950, 900, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10 mb). Values at the pressure levels below the surface should be filled with missing values (-999.0).

6. Output files

All output should be submitted in NetCDF format. Single precision should suffice for our purposes. Six example Fortran files have been provided for the six different types of output. However, please note that depending on number of tracers you plan to simulate (since some of the tracers are supplementary), care is needed to appropriately define the number of tracer (parameter 'ntracer') in some of the Fortran files. Use of missing values for unavailable tracers should be avoided to save disk space. If you choose not to use the example code, please take particular care when writing out character strings; please ensure that the strings are left-justified and padded with blanks to fill the length of the string.

6.1 Tracer concentration timeseries at all sites (write_alltracer.f)

Filename: all.your_model.your_institution.year.nc e.g. all.ACTM.RIGC.YYYY.nc
Dataset names: 'latitude', 'longitude', 'level', 'land', 'time', 'site_name', 'tracer_name', 'conc'.
Contents: Four arrays with location information that you will need to provide, time, site name and tracer name arrays that are generated by the example code and the tracer concentration array. In each array the sites should be ordered as given in the site list files.
Longitude: One value per site. Give the longitude of the model grid point that you sampled for this site or the real longitude if you interpolated between gridpoints.
Latitude: One value per site. Give the latitude of the model grid point that you sampled for this site or the real latitude if you interpolated between grid points.
Level: One value per site. Give the number of the model level that you sampled for this site (counting the model levels from the surface upwards). If you interpolated between model levels give the model level as a decimal, for example use 1.3 to represent level_1*0.7+level_2*0.3. If the interpolation changed in time, give an average value.
Land: One value per site. Give the surface type of the sampled grid point using 0 for ocean and 1 for land. If you model has fractional land then give the appropriate value between 0 and 1.
Concentration: A three dimensional array, conc(site,tracer,time) where site=280, tracer=9 and time=8760/8784. The tracers should be ordered as in Table 1 above. The concentrations should be hourly, instantaneous values starting at 01:00Z on 1 January and ending at 24:00Z 31 December of each year. If possible try to sample the model output at the 'end' of the timestep, that is after any mixing of the surface flux out of the surface layer and after radon decay. If you are unable to provide data at hourly temporal resolution please adjust the time dimension as applicable and submit as near to hourly resolution as you are able. The units for all CH_4 simulations should be ppb, for SF_6 and MCF ppt, and for Radon volume mixing ratio*10^{-21}.

6.2 Tracer concentrations at pressure/height levels at subset of sites (write_tracer.f)

Filename: Example code writes one file per tracer per year, tracer_name.your_model.your_institution.year.nc

Dataset names: 'latitude', 'longitude', 'time', 'conc', 'flux'.

Contents: Three arrays with location information that you will need to provide, time and site name arrays that are generated by the example code and the tracer concentration and surface flux arrays. In each array the sites should be ordered as given in the site list files. Longitude, latitude and land: as in section 6.1. Note that the level array is not applicable here.

Concentration: A three dimensional array, conc(site,lev,time) where time=8760 or 8784 and lev will depend on your model. Please submit the number of levels required in your model to reach on average to 10,000 m (use the same number of levels for all locations regardless of local topography). The level data should be ordered from the surface layer upwards. As in sec 6.1, the concentrations should be hourly instantaneous values starting from 01:00Z 1 January for respective years. The units for all CH_4 simulations should be ppb, for SF_6 and MCF ppt, and for Radon volume mixing ratio*10^{-21}.

Surface flux: A two-dimensional array, flux(site,time) where site=115 and time=8760 or 8784. Save the surface flux being used in the model at the same times that the tracer concentration data are saved, i.e. the surface flux that was used in the timestep that has just been completed. Units should be mol m^{-2} s^{-1} for each tracer. This array will be useful for diagnosing differences between modelled concentrations, as it is important to know how similar the prescribed fluxes were once aggregated to different model grids.

6.3 Monthly-mean tracer concentrations pressure levels (write_mmean_3d.f)

Filename: Example code writes one file per tracer, mmean.your_model.your_institution.tracer_name.nc

Dataset names: 'latitude', 'longitude', 'pressure', 'time', 'conc'.

Concentration: A four dimensional array, conc (lon,lat,lev,time) where time=12 month × number of years, lev=17, and lat, lon will depend on your model horizontal resolution. The pressure level data should be ordered from the surface layer upwards. The units for all CH_4 simulations should be ppb, for SF_6 and MCF ppt, and for Radon volume mixing ratio*10^{-21}. The 3D maps would be compared with HALOE observations in the lower stratosphere region for the 1992 onwards.

6.4 Daily tracer concentrations pressure levels (write_daily_3d.f)

Filename: Example code writes one file per tracer per year, daily.your_model.your_institution.year.tracer_name.nc

Dataset names: 'latitude', 'longitude', 'pressure', 'time', 'conc'.

Concentration: A four dimensional array, conc (lon,lat,lev,time) where time=365/6 days, lev=17, and lat, lon will depend on your model horizontal resolution. The pressure level data should be ordered from the surface layer upwards. The units for all CH_4 simulations should be ppb. The 3D maps would be compared with SCHIAMACHY, AIRS, IASI etc. remote sensing products. Therefore, it is recommended that model output is sampled at around 13:00 local time (LT).

6.5 Global total loss rates

Monthly-mean global total loss rates due to OH, Cl, O^1D (combined) for tracking the budget of sources, sinks and atmospheric burden for individual models. Please use simple ascii formatted files for this purpose with columns arranged as "Year Month Loss_Rate Loss_Rate_Troposphere Loss_Rate_Stratosphere". The last two columns are optional. An example program (loss_estimate.f90) is given for your reference, along with the input files from ACTM monthly mean values (actm_density_CH4.nc, actm_loss_CH4.nc, actm_geo_height.nc and actm_sfc_height.nc). The units for loss rates should be Tg-CH_4/yr.

6.6 Meteorological data at multiple levels for subset of sites (write_met.f)

Filename: met.your_model.your_institution.year.nc (one file per year)

Dataset names: 'latitude', 'longitude', 'land', 'time', 'site_name', 'pressure', 'height', 'u', 'v', 'surfpres', 'blh', 'cc'

Contents: Three arrays with location information that you will need to provide, time and site name arrays that are generated by the example code and the pressure, height, u and v component winds, surface pressure, boundary layer height and cloud cover. In each array the sites should be ordered as given in the site list files.

Longitude, latitude and land: as in section 6.1. Note that the level array is not applicable here.

Pressure, Height, u, v: Three-dimensional arrays, pressure(site,lev,time), height(site,lev,time), u(site,lev,time), v(site,lev,time), where site=115, lev is the same as in section 6.2 and time=8760 or 8784. Save the pressure, height and u and v wind components at the same model levels and times for which the concentration data have been saved in sec 6.2. Stick to the convention that positive u,v indicates eastward/northward winds. Units for pressure should be hPa, height should be 'm' and for u and v, '$m\ s^{-1}$'.

Surface pressure, boundary layer height and cloud cover: Two dimensional arrays, surfpres(site,ntime), blh(site,time), and cc(site,time) where site=115 and time=8760 or 8784. Save the surface pressure, boundary layer height and cloud cover at the same times for which the concentration data have been saved in sec 6.2. If you cannot easily extract the boundary layer height from your model then fill the array with a missing value of -999. Units for surface pressure are hPa and for boundary layer height, m. Modellers should report the % cloud cover (all cloud types) at the cloudiest level between the surface and 500 hPa. If this is not a parameter available to you, and you cannot calculate it easily we suggest to report either -999, or make your own choice and describe (in the Model_info file) what has been reported.

6.7 Model information file

Please complete the blank model information file, which can be downloaded from the 'transcom-ch4/output' directory.

7. Timetable and submission instructions

October 2009: Protocol distributed and input files available for download.
March 31, 2010 (or earlier): Submission of output. If you plan to make a submission but are unable to meet this deadline, please contact Prabir Patra.
Analysis will continue through 2009 and 2010.
We would encourage many people to be involved in the analysis of these results in many different ways, such as site specific analysis or global scale analysis in comparison with satellite data.

7.1 Submission instructions

The NetCDF files of output plus the ASCII model information file should be uploaded to the ftp site, fxp.nies.go.jp. Log in using the username and password given above. Please put your model output in the subdirectory 'transcom-ch4/output' in a directory formatted as 'model.group.submissiondate', e.g. 'TM5.SRON.2009-08-15/'. If you have to revise your submission, make a new directory and delete the old version.

7.2 Access to data for analysis

We would like to open the data for analysis to the whole of the TransCom, other Chemistry-Transport Modelling communities (e.g., AC&C, HTAP), and WMO World Data Center for Greenhouse Gases (WDCGG). We therefore intend to make the ftp site username and password available through the TransCom and other email list. Any model output could be downloaded by going to the 'transcom-ch4/output' subdirectory. Code for reading the all site file and selecting an individual site for ascii output is available in the 'transcom-ch4/sites_program' directory (extractsite.f). We also plan to provide files containing all the output from all models for one site (for those who do not wish to download the full dataset). Appropriate acknowledgement of modellers is required in any publications using this data.

8. Further information

Any questions should be directed to Philippe Bousquet (bousquet@lsce.ipsl.fr), Sander Houweling (s.houweling@sron.nl), Maarten Krol (maarten.krol@wur.nl), Prabir Patra (prabir@jamstec.go.jp).

Acknowledgements. Thanks are due to Rachel Law, Huisheng Bian, Annemarie Fraser, Shamil Maksyutov for comments, suggestions and technical corrections. Generous support of the NIES team with the disk space and FTP services is greatly appreciated.

Appendix 1: Globally integrated CH_4 emissions in mol s^{-1} for different flux combinations

YEAR	MM	CTL	CTL_E4	BB	WL_BB	INV	EXTRA
ANNUAL MEANS							
1988		1064415	1053295	1064739	1060132	1064791	1065147
1989		1066540	1061380	1066681	1062256	1071179	1058766
1990		1067653	1062168	1067652	1063369	1117780	1071501
1991		1068623	1060584	1068623	1064339	1106361	1069736
1992		1069594	1060744	1069594	1065310	996989	1044345
1993		1070566	1058244	1070565	1075007	1046746	1066813
1994		1071536	1059374	1071535	1076180	1066112	1077143
1995		1072466	1064918	1072506	1080155	1062940	1079152
1996		1073106	1068138	1073089	1088733	1068813	1070627
1997		1073527	1068130	1095525	1079442	1038423	1100413
1998		1072945	1069237	1093248	1094295	1086768	1127876
1999		1073341	1071467	1069728	1054125	1067377	1073148
2000		1074094	1072867	1062967	1024425	1040878	1065173
2001		1073718	1077546	1065608	1072834	1055516	1062273
2002		1073172	1088063	1072293	1079134	1093842	1066175
2003		1073872	1102126	1070137	1076790	1098193	1059895
2004		1073645	1118587	1073190	1079901	1058089	1056316
2005		1073851	1131837	1074250	1080726	1074843	1070365
2006		1073908	1136043	1072418	1079101	1074843	1077724
2007		1073908	1137407	1073759	1080332	1074843	1064244
2008		1073908	1138016	1060363	1068031	1074843	1058697
MONTHLY MEANS FOR YEAR 2000 (for an example)							
2000	1	922806	926726	916751	874675	883471	933546
2000	2	923458	927271	917179	863257	907149	940109
2000	3	983989	986685	961612	920005	997196	953252
2000	4	970213	972771	966837	922059	982299	1023107
2000	5	1075153	1075161	1064628	1008290	967728	1081339
2000	6	1240958	1236570	1218933	1179224	1034054	1255540
2000	7	1322527	1314122	1306634	1338594	1261572	1250177
2000	8	1341292	1331175	1330796	1357325	1356822	1270661
2000	9	1208557	1200526	1205819	1112038	1225766	1149026
2000	10	1042112	1037825	1033048	975076	1077683	1051209
2000	11	942997	944282	922856	882645	934700	954159
2000	12	915068	921284	910507	859910	862093	919950

Appendix 2: Integrated CH_4 soil sink in mol s^{-1} for different months

MONTH	CH_4 Global Soil Sink
1	-52379
2	-57975
3	-52315
4	-54105
5	-52519
6	-54388
7	-52683
8	-52731
9	-54512
10	-52732
11	-54433
12	-52593

Appendix 3: Integrated SF_6 emissions in mol s^{-1} for different years.

YEAR	SF_6 Global Source
1988	0.933607
1989	0.937848
1990	1.035538
1991	1.115968
1992	1.209193
1993	1.302532
1994	1.380830
1995	1.391749
1996	1.311382
1997	1.207016
1998	1.161551
1999	1.176746
2000	1.198524
2001	1.196330
2002	1.222267
2003	1.259139
2004	1.270163
2005	1.302712
2006	1.365676
2007	1.474235
2008	1.476406
2009	1.498118

Appendix 4: Integrated Radon emissions in mol s^{-1} (see below for lat/lon distribution)

YEAR	RADON Global Source
ALL YEAR	2.2 E-06

Radon emissions distribution and decay:
Construct your own radon emission distribution based on the surface type in each grid-cell and the fluxes in Appendix 4. For models with a defined land fraction, use the appropriate proportion of land and ocean emissions. We do not want the emission field to be rescaled to match a global total source but you should check that you produce a global radon source of approximately 2.2E-6 mol s^{-1}.

Surface type	Latitude range	Flux (mol m^{-2} s^{-1})
Land and ocean	70º-90ºN, 70º-90ºS	0
Land and ocean	60º-70ºN, 60º-70ºS	8.30e-23
Land	60ºS-60ºN	1.66e-20
Ocean	60ºS-60ºN	8.30e-23

Radon decays in the atmosphere with a half-life of 3.8 days. At each model timestep, apply the following

$$Rn(i,j,k) = \exp(-dtime*2.11e-6)*Rn(i,j,k)$$

where Rn is the radon mixing ratio at all gridpoints and dtime is the model timestep in seconds.

Appendix 5: Integrated MCF emissions in mol s^{-1} (Molecular Weight 133.42 g mol^{-1}) for different years.

YEAR	MCF Global Source
1988	157.3192
1989	163.5948
1990	169.9522
1991	150.8103
1992	140.8084
1993	91.69270
1994	69.04517
1995	57.48258
1996	24.38459
1997	11.55785
1998	7.579260
1999	6.543028
2000	6.162511
2001	4.223382
2002	3.828846
2003	3.132478
2004	2.557438
2005	2.100994
2006	1.720723
2007	1.404626
2008	1.149546

Appendix 6: Monthly mass weighted average J values ($J_{av,MCF}$; in s^{-1}) for ACTM results. The arithmetic means are also given (=sum of all valid numbers / total number of grid, including the ones with undefined values). If your model-mass weighted mean yielded a different value, please scale the J_{MCF} values for your model grid appropriately.

MONTH	Arithmetic Mean	Mass-Weighted Mean
1	2.5401753E-06	8.3476884E-08
2	2.4157671E-06	8.2390777E-08
3	2.2540328E-06	7.9968871E-08
4	2.2784384E-06	7.8350105E-08
5	2.3562375E-06	7.7814576E-08
6	2.4044273E-06	7.8344584E-08
7	2.3875425E-06	7.8080348E-08
8	2.3036978E-06	7.7737212E-08
9	2.2119370E-06	7.7066154E-08
10	2.3052032E-06	7.9229252E-08
11	2.4704623E-06	8.1900090E-08
12	2.5604131E-06	8.3744482E-08