Protocol for SF$_6$ Experiments

Overview:

Each participating group will run a 5 year (1989-1993) global simulation of the mixing ratio of SF$_6$, using a common initial condition and surface emission scenario. We will each submit a series of output fields (described below) for the final year of the simulation (1993). The volume of data submitted by each group will be quite large, so it is very important for every group to adhere strictly to a specific data format to facilitate data analysis.

Results should be submitted by November 1, 1996.

Table 1: List of symbols used in this document

Symbol	Description	Units
χ	mole fraction of SF$_6$	pptv
C	mass mixing ratio of SF$_6$	kg (SF$_6$) kg^{-1} (dry air)
$C_{\text{bkg}}(t)$	global mass-weighted mean mixing ratio of SF$_6$	kg kg^{-1}
C_0	initial mass mixing ratio	kg kg^{-1}
$S(t)$	globally integrated source (emission rate) of SF$_6$	kg s^{-1}
C^+	local excess of C relative to global mean	kg kg^{-1}
M_a	mass of the atmosphere in your model	kg
M_{SF6}	global mass of SF$_6$ in the model atmosphere	kg
p	atmospheric pressure	Pa (or mb)
p_{s}	surface pressure	Pa
$\sigma = p/p_s$	normalized pressure (vertical coordinate)	
u	zonal wind velocity	m s^{-1}
v	meridional wind velocity	m s^{-1}
ω	vertical pressure velocity (positive downward)	Pa s^{-1}
g	acceleration of gravity	m s^{-2}
$[\dots]$	zonal mean of quantity inside brackets	
$[\dots]^R$	"representative" zonal mean (terrain corrected, see section 3.3.1)	
$(\dots)^*$	local departure from zonal mean	
$\overline{(\dots)}$	time (monthly) mean	
$\overline{(\dots)}^R$	"representative" time mean (terrain corrected, see section 3.3.1)	
$(\dots)'$	instantaneous departure from time mean	

1. Initial Condition:

All the models will be initialized with a globally uniform concentration field. The global mean concentration of SF_6 on January 1, 1989 was 2.06 parts per trillion by volume (pptv), using the model of Maiss *et al* (1996). This is equivalent to a mass mixing ratio of 1.04×10^{-11}. If you start your model before Jan. 1, 1989 (say, Dec. 1, 1988) it is not necessary that the tracer field be globally uniform on January 1, 1989, only that the global, mass-weighted mean concentration is 2.06 pptv.

NOTE: Transport diagnostics will be calculated *after subtracting the global mean* mixing ratio, so use of a different initial condition will not affect them. If you choose to use a different initial condition, be sure to add the appropriate offset to the concentration fields used to compare to observations.

2. Prescribed Surface Emissions:

We will use the annual global emission estimates of Levin and Hesshaimer (1996) as a boundary condition. These global estimates have been interpolated to monthly values defined on the 15th of each month between December 1988 and January 1994 so that we can avoid any "shocks" associated with rapidly changing emission rates at year boundaries. The global emissions will be distributed geographically according to electrical power usage as estimated by Martin Heimann (personal communication) from the UN Energy Statistics Yearbook (1992) by country and population density (5' population map of CIESIN).

To produce **62 monthly maps of** SF_6 **emissions** on each group's specific model grid:

1) Average the distribution function onto your model grid.

2) Rescale the gridded distribution function to obtain a global integral of 3.170979198e-02.

3) Multiply this distribution function by the monthly global emission rates to obtain maps of SF_6 emissions in kg m^{-2} s^{-1}.

To download the monthly emission boundary conditions on the $0.5° \times 0.5°$ grid, obtain the file SF$_6$**.emissions.tar.gz** or SF$_6$**.emissions.tar.Z** from the **transcom ftp** archive at **kiwi.atmos.colostate.edu**. Be sure to transfer the file in *binary* mode. A **README** file is included in the **tar** archive explaining in detail how to generate the monthly emission maps from the included data.

3. Required Model Output:

3.1   Maps

Maps of model diagnostics are to be provided as monthly means in arrays of dimension **IM** × **JM**, where **IM** is the number of longitudes and **JM** is the number of latitudes in your model. Each set of diagnostics is described in terms of filenames that should be used, a formula defining it, and a brief description. For more information regarding the specific format of the output files, please see section 4 below.

Note that *interpolation to pressure coordinates and computation of products must be done before time averaging*. This will allow quantitative comparison of the effects of resolved and parameterized transport among the models.

Table 2: Maps (12 monthly means)

File(s)	Diagnostic	Description
`C.sfc`	χ_{sfc}	Mole fraction of SF$_6$ at surface or in lowest layer (pptv)

`C.lo`
`C.mid`
`C.hi`
	$\int_{p_1}^{p_2} C^+ dp/g$	Mean mass per unit area of SF$_6$ between p_1 and p_2 (kg m^{-2})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`uC.lo`
`uC.mid`
`uC.hi`
	$\int_{p_1}^{p_2} uC^+ dp/g$	Resolved zonal flux of SF$_6$ between p_1 and p_2 (kg m^{-1} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`vC.lo`
`vC.mid`
`vC.hi`
	$\int_{p_1}^{p_2} vC^+ dp/g$	Resolved meridional flux of SF$_6$ between p_1 and p_2 (kg m^{-1} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`omegaC.700` `omegaC.350`	$\beta\omega C^+/g$	Resolved vertical (downward) flux of SF$_6$ (kg m^{-2} s^{-1}) 2 maps: at 700 mb and 350 mb

`u.lo`
`u.mid`
`u.hi`
	$\int_{p_1}^{p_2} u\, dp/g$	Zonal mass flux *of air* between p_1 and p_2 (kg m^{-1} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`v.lo`
`v.mid`
`v.hi`
	$\int_{p_1}^{p_2} v\, dp/g$	Meridional mass flux *of air* between p_1 and p_2 (kg m^{-1} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`omega.700` `omega.350`	$\beta\omega/g$	Vertical (downward) mass flux *of air* (kg m^{-2} s^{-1}) 2 maps: at 700 mb and 350 mb

`y-diff.lo`
`y-diff.mid`
`y-diff.hi`
	$\frac{1}{g}\int_{p_1}^{p_2} k_y \frac{\partial^2 C}{\partial y^2} dp$	SF$_6$ tendency due to meridional diffusion (kg m^{-2} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`z-diff.lo`
`z.diff.mid`
`z-diff.hi`
	$\frac{1}{g}\int_{p_1}^{p_2} k_z \frac{\partial^2 C}{\partial z^2} dp$	SF$_6$ tendency due to vertical diffusion (kg m^{-2} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`CONVEC.lo`
`CONVEC.mid`
`CONVEC.hi`
	$\int_{p_1}^{p_2} \left(\frac{\partial C}{\partial t}\right)_{cumulus} \frac{dp}{g}$	SF$_6$ tendency due to cumulus convection (kg m^{-2} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`dry.lo`
`dry.mid`
`dry.hi`
	$\int_{p_1}^{p_2} \left(\frac{\partial C}{\partial t}\right)_{dry} \frac{dp}{g}$	SF$_6$ tendency due to dry convection (kg m^{-2} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

`subgrid.lo`
`subgrid.mid`
`subgrid.hi`
	$\int_{p_1}^{p_2} \left(\frac{\partial C}{\partial t}\right)_{subgrid} \frac{dp}{g}$	All *vertical* sub-grid scale processes (kg m^{-2} s^{-1})
		3 maps: (sfc to 700 mb), (700 to 350 mb), (350 mb to top)

It is recognized that not all models will have the same set of sub-grid scale processes acting, which is why we are providing the sum of the tendencies arising from all vertical subgrid-scale parameterizations together. **NOTE** that this sum should not include horizontal diffusion, which operates on a much larger spatial scale than convective processes.

If you use a spectral model and do not have separate meridional and zonal diffusion, provide the tendency due to your net horizontal subgrid diffusion-like operator in the files `y-diff.xx`. If you have a convection scheme for the tracer that does not separate cumulus and dry convection (*e.g.*, convective adjustment) please provide the tendency due your convection scheme under the files `CONVEC.xx` and do not submit `dry.xx.`

The Earth's surface will sometimes intersect pressure surfaces used in the layer-integrated flux calculations requested above. Of course, the SF_6 flux at such a location (*e.g.*, under the Tibetan Plateau) is zero. Be sure to mask out such spurious "underground" tracer fluxes when calculating the integrals in Table 1. This issue also requires careful attention in computing zonal mean cross-sections and the eddy fluxes described below. Please read the discussion of ***"terrain masking"*** in section 3.3.1.

3.1.1 *"Normalization" of transport fields (removal of background mixing ratio):*

The advective tendency due to the three-dimensional mass transport of SF_6 in the atmosphere can be decomposed as

$$\nabla\bullet(VC) = \nabla\bullet[V(C_{bkg} + C^+)] = \nabla\bullet(VC_{bkg}) + \nabla\bullet(VC^+) = \nabla\bullet(VC^+) \qquad (1)$$

where V is the three-dimensional wind vector, C is the mass mixing ratio of SF_6, C_{bkg} is a "background" value of C (the global mass-weighted mean), and C^+ is the local deviation from this background mixing ratio. C_{bkg} is spatially uniform, so the transport due to this part of the field is nondivergent (in three dimensions) and therefore has no effect on the concentration field. We wish to "normalize" the transport diagnostics to remove this large but uninteresting term. Without such "normalization", the transport field is dominated by the wind field itself, so differences in the divergent part of the transport are difficult to see.

All transport fields involving SF_6 should be calculated after removing the global mass-weighted mean mixing ratio as follows. Define the "background" mixing ratio (kg kg^{-1}),

$$C_{bkg} \equiv \frac{M_{SF6}}{M_a} . \qquad (2)$$

The background mass mixing ratio should be calculated in the native vertical coordinate of your model, before interpolating to pressure coordinates, *e.g.*, for $\sigma = p/p_s$,

$$C_{bkg} = \frac{\iiint C(\lambda, \phi, \sigma)d\lambda\cos\phi d\phi p_s d\sigma}{\iint p_s(\lambda, \phi)d\lambda\cos\phi d\phi} . \qquad (3)$$

If your model is constructed so that mass conservation (of both tracer and air) is guaranteed, a more computationally efficient way to keep track of the background SF_6 field is to add the time-integrated surface emission field to the initial mixing ratio, *i.e.*,

$$C_{bkg} = C_0 + \left(\int_0^t S(t)dt \right) / M_a , \tag{4}$$

where C_0 is the initial mixing ratio (1.04×10^{-11} kg kg^{-1}), $S(t)$ is the time-varying global emission rate (kg s^{-1}), and M_a is the mass of the atmosphere (kg). In computing the resolved transport fields, subtract this background mixing ratio before computing the products, i.e., use C^+ as indicated in Table 2, where

$$C^+ \equiv C - C_{bkg} . \tag{5}$$

This normalization should be applied to *all diagnostic fields* (cross-sections and eddy decomposition as well as maps) that are not being compared to observational data. The only exceptions are the surface mole fraction and the high-frequency point time series.

3.2   *Zonal mean cross-sections*

Cross sections of monthly mean quantities will be saved as arrays of dimension **JM** × **LM**, where **JM** is the number of latitudes in your model, and **LM** is the number of pressure levels saved. The cross-section diagnostics are described in Table 3.

Preferred pressure levels are: 50, 100, 150, 200, 250, 300, 400, 500, 700, 850, 1000 mb. Again, interpolation to pressure coordinates and computation of products must be done *before* time averaging, and the global mass-weighted mean mixing ratio of SF_6 must be subtracted before computing the transport.

Please report zero resolved mass flux and zero tendency for all array cells which lie below the Earth's surface (see section 3.3.1 for a discussion of terrain masking)

3.3   *1-D Dimensional meridional profiles*

1-Dimensional meridional profiles of decomposed zonal mean meridional transport by the mean circulation, steady eddies, and transients will be provided for each pressure interval as defined above (sfc to 700 mb; 700 mb to 350 mb; 350 mb to model top) as 12 monthly means.

Note that the tracer mass mixing ratio to be used here is C^+, not C (see Table 1), but in this section we suppress the + for clarity.

Table 3: Zonal Mean Cross Sections (12 monthly means)

File(s)	Diagnostic	Description
C.x-sect	$[\bar{\chi}]^{K}$	Mole (volume) fraction of SF_6 (pptv)
v.x-sect	$[\bar{v}]^{K}$	Meridional velocity component (m s^{-1})
vC.x-sect	$[\overline{vC^{+}}]^{R}$	Meridional mass flux of SF_6 (kg m s^{-1})
y-diff.x-sect	$\left[\overline{k_y \dfrac{\partial^2 C}{\partial y^2}}\right]^{R}$	SF_6 tendency due to meridional diffusion (kg m^{-2} s^{-1})
z-diff.x-sect	$\left[\overline{k_z \dfrac{\partial^2 C}{\partial z^2}}\right]^{R}$	SF_6 tendency due to vertical diffusion (kg m^{-2} s^{-1})
CONVEC.x-sect	$\left[\overline{\dfrac{\partial C}{\partial t}_{cumulus}}\right]^{R}$	SF_6 tendency due to cumulus convection (kg m^{-2} s^{-1})
dry.x-sect	$\left[\overline{\dfrac{\partial C}{\partial t}_{dry}}\right]^{R}$	SF_6 tendency due to dry convection (kg m^{-2} s^{-1})
subgrid.x-sect	$\left[\overline{\dfrac{\partial C}{\partial t}_{subgrid}}\right]^{R}$	Tendency due to *all* sub-grid scale processes (kg m^{-2} s^{-1})
terrain.mask	$[\bar{\beta}]$	Zonal mean terrain mask (see section 3.3.1)

The decomposition of the meridional transport terms is described in Table 4. In the definitions in Table 4, the overbars indicate monthly means, the square brackets indicate the zonal mean, the asterisks indicate the local departure from the zonal mean, and the primes indicate the instantaneous departure from the monthly mean. The *R*'s associated with overbars and square brackets indicate that these are "*representative*" values for each latitude and time period (see Table 1). Note that each integrand must be multiplied by the zonal mean time mean of β, the terrain mask function (see below).

Table 4: Decomposition of Meridional Transport

Files	Diagnostic	Description
`mean-circ.lo` `mean-circ.mid` `mean-circ.hi`	$\int_{p_1}^{p_2} [\bar{\beta}][\bar{v}]^R [\bar{C}]^R dp/g$	transport by the mean circulation $(\text{kg m}^{-1}\text{ s}^{-1})$
`steady-eddies.lo` `steady-eddies.mid` `steady-eddies.hi`	$\int_{p_1}^{p_2} [\bar{\beta}][\overline{v^* C^*}]^R dp/g$	transport by the stationary eddies $(\text{kg m}^{-1}\text{ s}^{-1})$
`transients.lo` `transients.mid` `transients.hi`	$\int_{p_1}^{p_2} [\bar{\beta}][\overline{v'C'}]^R dp/g$	transport by the transient circulation $(\text{kg m}^{-1}\text{ s}^{-1})$

3.3.1 *"Terrain Masking"*

We have to take care to define "*representative*" means in both time and space in such a way as to exclude values that are "underground" when pressure surfaces are intersected by the Earth's surface. Such "*representative*" values should be defined so that the structure of the decomposition of covariance is the same as in the free atmosphere:

$$[\overline{(vC)}]^R = [\bar{v}]^R [\bar{C}]^R + [\overline{v^* C^*}]^R + [\overline{v'C'}]^R \quad . \tag{6}$$

As shown by Boer (1982), this can be straightforwardly accomplished by keeping careful track of the points above ground using a terrain mask and by carefully defining averages only over points above ground. Define the terrain mask, β, on pressure surfaces as

$$\beta = 1 \qquad \text{for } p < p_s$$
$$\beta = 0 \qquad \text{for } p \geq p_s \tag{7}$$

Note that $\beta(p)$ is just a step (or Heaviside) function with a unit step at $p = p_s$.

The representative zonal, monthly mean average of a quantity X is now defined by

$$[\bar{X}]^R = [\overline{\beta X}]/[\bar{\beta}] \quad .$$

The *"representative"* eddy terms above can be computed as follows:

1) Interpolate 3-D arrays of v, C, vC to pressure levels, and accumulate these values as monthly means: $\overline{\beta v}$, $\overline{\beta C}$, $\overline{\beta vC}$, and $\overline{\beta}$.

2) Compute the zonal mean of each of these variables: $[\overline{\beta v}]$, $[\overline{\beta C}]$, $[\overline{\beta vC}]$, and $[\overline{\beta}]$.

3) Compute representative monthly and zonal means, and deviations therefrom, as defined by:

$$\overline{C}^R = \overline{\beta C}/\overline{\beta} \qquad\qquad [\overline{C}]^R = [\overline{\beta C}]/[\overline{\beta}] \qquad\qquad \overline{C}^* = \overline{C}^R - [\overline{C}]^R$$

$$\overline{v}^R = \overline{\beta v}/\overline{\beta} \qquad\qquad [\overline{v}]^R = [\overline{\beta v}]/[\overline{\beta}] \qquad\qquad \overline{v}^* = \overline{v}^R - [\overline{v}]^R$$

(8)

4) The integrand of the "steady eddy" term is then given by $[\overline{v}^* \overline{C}^*]^R = [\overline{\beta}\,\overline{v}^*\overline{C}^*]/[\overline{\beta}]$.

5) The integrand of the "transient eddy" term is what is left over:
$$[\overline{v'C'}]^R = [\overline{\beta vC}]/[\overline{\beta}] - [\overline{v}^*\overline{C}^*]^R - [\overline{v}]^R[\overline{C}]^R \quad .$$

6) Take the vertical integrals over pressure layers as indicated in the definitions.

3.4   High-Frequency Time Series

Purpose: To assess the performance of the models on reproducing synoptic and diurnal time scale variations and how these are related to the monthly mean mixing ratios that are reported and analyzed within the other tasks of TransCom2.

3.4.1   Mandatory output:

(a) Time series of SF_6 *mixing ratio* for the entire final year of the simulation at the 20 locations given in the station list given below.

The SF_6 mixing ratio should be interpolated (preferably on-line) horizontally and vertically to the listed sampling locations. The technique employed may be chosen by each group; preferably you should use your standard interpolation schemes that you use when extracting model data for particular station locations. Each group must specify the shortest timestep that they deem to be appropriate for their model (*i.e.* the shortest timestep that may still be considered meaningful: *e.g.* one or two times the basic numerical timestep in the case of a GCM or the timestep of the meteorological analyses in the case of an off-line model) and report the mixing ratios at least with this time step.

(b) Explanatory datasheet

This datasheet must contain the following information:

1) time information:

- the appropriate timestep of the model and, if not the same, also the timestep of the provided output at the 20 station locations

- information as to whether the model uses UT

- the model time of the first record of the provided output

2) a brief description of the vertical interpolation scheme

3) a brief description of the horizontal interpolation scheme

3.4.2 *Extended high-frequency output:*

The mandatory output as defined above will only provide the high temporal resolution information at particular point locations. At least with respect to the models representation of vertical, high frequency transport processes, such as diurnal and synoptic situation dependent boundary layer variations, additional information is important. Thus, as a diagnostic tool, additional high frequency output at the geographical locations of the stations listed below is suggested. Note that while this output is not mandatory, it will allow a more comprehensive analysis and model intercomparison of the high frequency results. This analysis will only be performed for those models that provide this auxiliary output. Clearly, only station locations lying close to SF_6 sources will be really interesting with respect to diurnal variations and vertical gradients in the boundary layer. Because we can't decide beforehand which stations will be worth looking at, I suggest that the output should be provided for all the 20 locations given in the list.

(a) Vertical profiles of the SF_6 *mixing ratio*

Report the mixing ratio of SF_6 at all station locations on all model levels from the surface up to approximately 4000m. Because most models use a vertical coordinate system, in which the model layers change their height above ground with time (*e.g.* pressure, sigma or hybrid coordinates) we need in addition to the SF_6 mixing ratio in a second output data file also the heights above ground (in m) of each model layer.

Write the output for each station into two files, each containing in each line the output of a particular time instant and in each column the values of a different model layer, going upwards from left to right. Use the format n**f8.3** for the SF_6 mixing ratio and n**f6.0** for the heights above ground (*n* being the numbers of model layers below 4000m). Name the files **xv_sta.d** for the SF_6 mixing ratio and **h_sta.d** for the level heights (**sta=CGO, NEU, CGO**, *etc*.) (These files are not extremely large: a model with a 1hour timestep and 10 layers below 4000m will result in approximately 1.2 MB per station which will be much smaller after compression).

(b) Meteorological information

We also need the model meteorology at the stations in order to correlate the vertical structure of SF_6 to simple measures of vertical stability. We therefore ask to provide on the same model layers the meteorological variables listed in Table 5:

Put each variable for each station into a separate file identified with the filenames listed above in parentheses (where **sta=SPO, NEU, CGO**, etc.). Station data are listed in Table 6. SF_6 data are either already existing or will become available for most of the 20 locations. Elevations are given for the main sampling location (at the TV towers there are additional sampling levels).

Table 5: Station Meteorological Information

Files	Description
`t_sta.d`	Temperature (K) on same levels as SF_6 output
`q_sta.d`	specific humidity (kg kg^{-1}) on same levels as SF_6 output
`v_sta.d`	horizontal wind speed (m s^{-1}) on same levels as SF_6 output
`ps_sta.d`	Surface pressure (Pa)
`bh_sta.d`	Boundary-layer depth (m) (if computed by your model)

Table 6: Station Locations

Code	Station Name	Lat	Long	Elev (m)
SPO	South Pole	90 S	102 W	2835
NEU	Neumayer	71 S	8 W	42
TDF	Tierra del Fuego	54 52' S	68 29' W	20
CGO	Cape Grim	41 S	145 E	95
SMO	Samoa	14 14' S	170 34' E	77
RPB	Ragged Point Barbados	13 10' N	59 26' W	3
GMI	Guam, Mariana Islands	13 26' N	144 47' E	2
MLO	Mauna Loa, Hawaii	19 32' N	155 35' W	3397
IZO	Izana	28 N	16 W	2367
BME	St. Davids Head, Bermuda	32 22' N	64 39' W	30
WITN	North Carolina TV tower	35 37' N	77 39' W	496
QPC	Qinghai Province	36 16' N	100 55' E	3810
UTA	Wendover, Utah	39 54' N	113 43' W	1320
WLEF	Park Falls Wisconsin TV tower	45 56' N	90 16' W	868
HUN	Hegyhatsal, Hungary	46 58' N	16 23' E	240
FRA	Fraserdale, Quebec	50 N	82 W	200
MHT	Mace Head, County Galway	53 20' N	9 54' W	26
CBA	Cold Bay, Alaska	55 12' N	162 43' W	25
SVA	Svalbard (Spitzbergen)	78 55' N	11 53' W	474
ALT	Alert, NWT	82 27' N	62 31' W	210

4.   Output format:

The much larger volume of data in Phase 2 than Phase 1 dictates that we must be very clear about output formats for storage efficiency, and (especially) to facilitate data analysis. Please read the specifications below *very carefully* before extracting and packaging your model output.

Please don't just submit the data in whatever form is easiest for you to produce!

This will be a lot of work, but the effort will be well justified in reduced transfer time, disk space requirements, and frustration on the part of the data analyst(s).

The total data requirement for the maps is (34 fields × 12 months × **IM** × **JM**) values. For a 2° × 2° grid, this will be about 25 MB. For a 4° × 5° model, this will be about 4.9 MB.

The total data requirement for the cross-sections is (8 fields × 12 months × **JM** × **LM**) values. For a 2° × 2° model, this will be about 0.4 MB.

The storage requirement for the 1-D profiles is negligible, so please provide the numbers as ASCII files of two columns per profile (12 profiles per file, see discussion below under "File formats"), with the first column giving the latitude of the zonal strip and the second column giving the flux.

4.1   Directory Structure and Filenames:

Create a directory that has the name of your model as you want it to appear in the report (I will use "**CSU**," Martin Heimann will use "**TM3**," etc.). Inside this directory, create three subdirectories named "**Maps**," **CrossSections**," and "**Profiles**." Each group will produce *38 separate files*, one for each variable (and pressure interval). Each file will contain *12 arrays in sequence*, corresponding to monthly means for January, February, March, *etc*.

After creating all of these files, place them in a single directory and use the **Unix** utilities "**tar**" and "**gzip**" (or "**compress**") to package them into a single file of the smallest possible size. This will help you transfer the files via **ftp**.

Please use *exactly* the following names for your files. Variables are listed here in the same order they appear (with definitions) in the tables on the previous pages.

Subdirectory Maps:

```
C.sfc
C.lo              C.mid             C.hi
uC.lo             uC.mid            uC.hi
vC.lo             vC.mid            vC.hi
omegaC.700        omegaC.350
y-diff.lo         y-diff.mid        y-diff.hi
z-diff.lo         z-diff.mid        z-diff.hi
CONVEC.lo         CONVEC.mid        CONVEC.hi
dry.lo            dry.mid           dry.hi
subgrid.lo        subgrid.mid       subgrid.hi
```

Subdirectory `CrossSections`:

```
C.x-sect            v.x-sect            vC.x-sect        y-diff.x-sect
z-diff.x-sect       CONVEC.x-sect       dry.x-sect       subgrid.x-sect
```

Subdirectory `Profiles`:

```
mean-circ.lo        mean-circ.mid       mean-circ.hi
steady-eddies.lo    steady-eddies.mid   steady-eddies.hi
transients.lo       transients.mid      transients.hi
```

4.2   File format:

To save disk space, these files should be written as ***unformatted binary*** data, with one array per record. For example, the following Fortran code fragment could be used to produce the file of 12 monthly mean zonal SF_6 flux maps for 350 mb to 700 mb:

```
parameter (im=72, jm=44)
real uClo(im,jm,12)
open(unit=1, file='uC.lo', form='unformatted')
do month = 1, 12
   write(1) ((uClo(i,j,month), i=1,im), j=1,jm)
end do
close(1)
end
```

I strongly prefer that you use **IEEE 32-bit standard Fortran-77 binary**, although I can read almost anything if I must. In particular, it is essential that you tell me if you have used a C or IDL program or some non-standard binary format (*e.g.* Cray binary).

4.3   File structure and formatting for timeseries output:

Please submit the timeseries output separately (not in the above-described directory structure), as it will be analyzed at another physical location. Create a directory named with your model identifier as above, with the suffix ".ts" (for timeseries, *e.g.*, "`CSU.ts`"). Create subdirectories "`Mandatory`" and "`Extended`" under the "`your-model.ts`" directory.

Subdirectory `Mandatory`:

```
x_all.d             DESCRIPTION
```

Or ...

```
x_SPO.d             x_NEU.d             x_TDF.d          x_CGO.d
x_SMO.d             x_RPB.d             x_GMI.d          x_etc.d

DESCRIPTION
```

Preferably, write all the timeseries into one single formatted file (`x_all.d`) with each line containing the data for a particular time instant, written by the format `20f8.5`. Thus each column will correspond to one station, with the order of the stations as in the table given below. Alternatively, you can write a formatted file for each station. In this case identify the files by the names '`x_sta.d`', where (`sta=SPO, NEU, CGO`, *etc*., for a total of 20 station files) and write on each line one value per time instant with the format `f8.5`. The file `DESCRIPTION` should contain the information described in section 3.4.1(b) above.

Subdirectory `Extended`:

```
xv_stn.d      h_stn.d
t_stn.d       q_stn.d          v_stn.d          ps_stn.d          bh_stn.d
```

20 files each for 7 variables (total of 140 files, see section 3.4.2).

4.4   Archival, compression, and data transfer:

1)   After you have generated the 44 required output files, and placed them in the directory structure described above, create a single file ("`tar` archive") of this directory by typing (for example):
```
tar –cf CSU.tar CSU
```

NOTE: People with high-resolution models and/or slow ftp connections to the US may break up their archives if necessary and send me the pieces. Please let me know if you are going to do this.

2)   Compress the `tar` archive. A smaller compressed file will be obtained if you use the Gnu utility "`gzip`," but the standard `Unix` utility "`compress`" is acceptable if you don't have `gzip`:
```
gzip CSU.tar
```

In this example, I would have created the file `CSU.tar.gz`, which will be smaller than the original `CSU.tar`.

3)   Transfer the file via ftp to `kiwi.atmos.colostate.edu`, in ***binary*** mode, as follows:
```
ftp –ni kiwi.atmos.colostate.edu
user transcom model2
cd Output/your-name
binary
put model-name.tar.gz
bye
```

In the above example, I would replace *your-name* with "`scott`" and *model-name* with "`CSU`."

As of now, I will plan to use the same directory names as we used in TransCom Phase 1. Let me know if you want to be known by a different identifier in Phase 2.

5. References:

G. J. Boer, 1982, *Monthly Weather Review*, **110**, 1801.

Harnisch, J., Borchers, R., Fabian, P., and Maiss, M, 1996. Tropospheric trends of CF_4 and C_2F_6 since 1982 derived from SF_6 dated stratospheric air. *Geophys. Res. Lett.*, **23**, 1099.

Levin, I., and V. Hesshaimer, 1996. Refining of atmospheric transport model entries by the globally observed passive tracer distributions of ^{85}Kr and sulfur hexafluoride (SF_6). Submitted to the *Journal of Geophysical Research*.

Maiss, M. and Levin, I., 1994. Global increase of SF_6 observed in the atmosphere. *Geophys. Res. Let.*, **21**, 569-572.

Maiss, M., L. P. Steele, R. J. Francey, P. J. Fraser, R. L. Langenfelds, N. B. A. Trivett, and I. Levin, 1996. Sulfur Hexafluoride - a powerful new atmospheric tracer. *Atmospheric Environment*, **30**, 1621-1629.