5 Fun Things To Do With WACCM

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- How do I change model output?
- How do I change a reaction rate?
- How is the solar spectrum specified?
- How do I change a boundary condition?
- How do I change an initial condition?

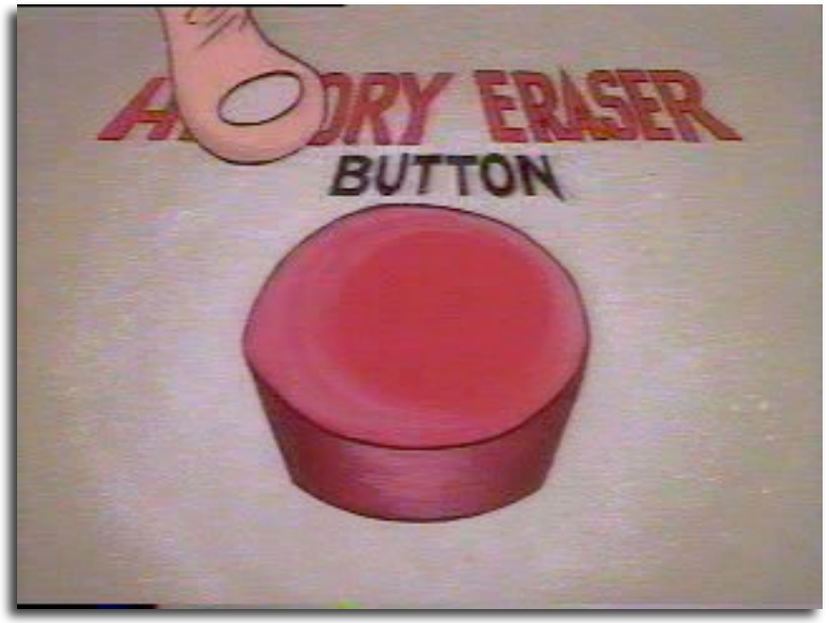
How do I change model output?

- Review list of current CAM history variables
  - Currently >2300 existing CAM history variables
  - Complete list is printed in atm.log.* file generated during each run in $rundir/run.
  - Search log file for "`MASTER FIELD LIST`" to review.

```
******* MASTER FIELD LIST *******
  1 US                    m/s
  2 VS                    m/s
  3 US&IC                 m/s
  4 VS&IC                 m/s
  5 PS&IC                 Pa
  6 T&IC                  K
  7 Q&IC                  kg/kg
  8 CLDLIQ&IC             kg/kg
  9 CLDICE&IC             kg/kg
 10 O3&IC                 kg/kg
 11 O&IC                  kg/kg
 12 O1D&IC                kg/kg
 13 O2&IC                 kg/kg
 14 O2_1S&IC              kg/kg
 15 O2_1D&IC              kg/kg
 16 N2O&IC                kg/kg
 17 N&IC                  kg/kg
 18 NO&IC                 kg/kg
 19 NO2&IC                kg/kg
 20 NO3&IC                kg/kg
 21 HNO3&IC               kg/kg
 22 HO2NO2&IC             kg/kg
 23 N2O5&IC               kg/kg
 24 CH4&IC                kg/kg
 25 CH3O2&IC              kg/kg
 26 CH3OOH&IC             kg/kg
 27 CH2O&IC               kg/kg
 28 CO&IC                 kg/kg
 29 H2&IC                 kg/kg
 30 H&IC                  kg/kg
 31 OH&IC                 kg/kg
 32 HO2&IC                kg/kg
 33 H2O2&IC               kg/kg
 34 CLY&IC                kg/kg
 35 BRY&IC                kg/kg
 36 CL&IC                 kg/kg
 37 CL2&IC                kg/kg
 38 CLO&IC                kg/kg
 39 OCLO&IC               kg/kg
 40 CL2O2&IC              kg/kg
 41 HCL&IC                kg/kg
 42 HOCL&IC               kg/kg
 43 CLONO2&IC             kg/kg
 44 BRCL&IC               kg/kg
 45 BR&IC                 kg/kg
 46 BRO&IC                kg/kg
 47 HBR&IC                kg/kg
 48 HOBR&IC               kg/kg
 49 BRONO2&IC             kg/kg
 50 CH3CL&IC              kg/kg
 51 CH3BR&IC              kg/kg
 52 CFC11&IC              kg/kg
 53 CFC12&IC              kg/kg
 54 CFC113&IC             kg/kg
 55 HCFC22&IC             kg/kg
 56 CCL4&IC               kg/kg
 57 CH3CCL3&IC            kg/kg
 58 CF3BR&IC              kg/kg
 59 CF2CLBR&IC            kg/kg
 60 CO2&IC                kg/kg
 61 N2p&IC                kg/kg
 62 O2p&IC                kg/kg
```

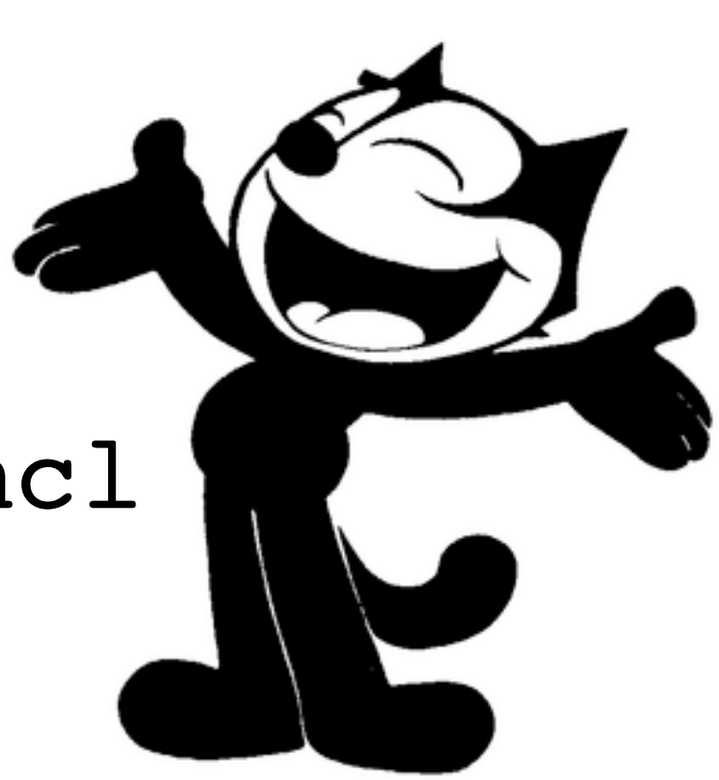
How do I change model output?

- Case 1: Existing history variable
  - Adding/deleting history variables to output
  - Changing frequency or averaging of output



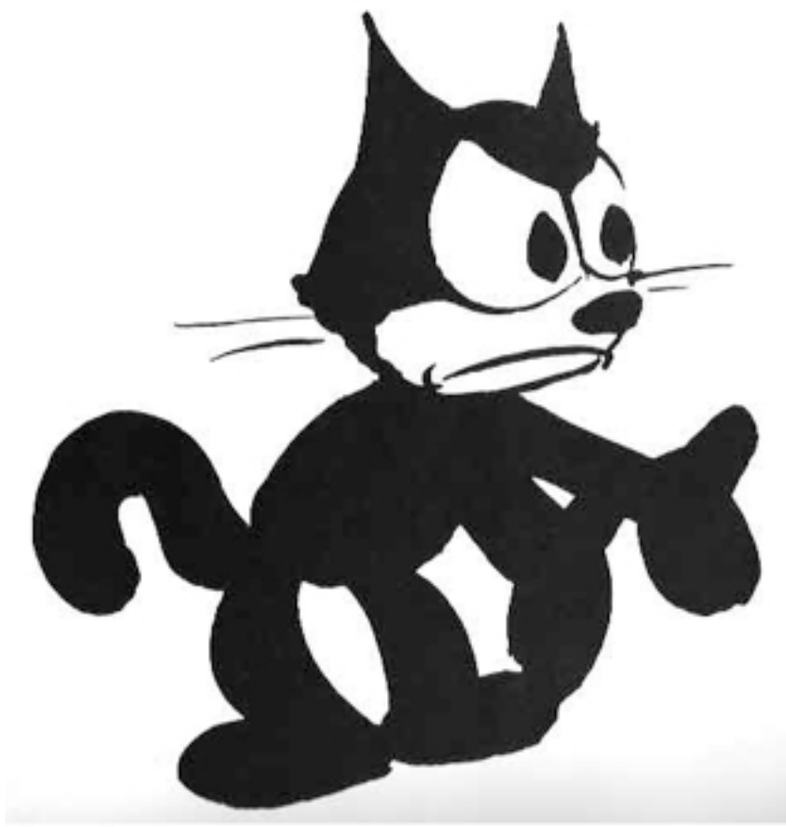
- Case 2: Create new history
  - Modifying source code
  - Call routines `addfld` & `outfld`
  - compiling with modified source code

`fincl` and `fexcl`: 2 cool cats controlling history



`fincl`

- Lists history variables that you want to include in model output, in addition to default history variables.



`fexcl`

- Lists default history variables that you want to exclude from model output

History file series

CAM output can be sent to numerous history file series, each of which may have independent output variables, frequency and averaging characteristics.

- The **first** history file series is monthly averaged output by default, producing files named `$case.cam2.h0.YYYY-MM.nc`
- Additional history file series may be of arbitrary frequency, averaged or instantanous.
  - Series 2 : `$case.cam2.h1.*`
  - Series 3 : `$case.cam2.h2.*`
  - `etc.`
- Each series has its own fincl and fexcl, BUT...

fincl1→h0

fincl2→h1

fincl3→h2

How do I change output of existing namelist variables?

- After you configure a case, edit $casedir/Buildconf/cpl.buildnml.csh:

```
&cam_inparm
       avgflag_pertape     = 'A', 'I',  'I', 'A', 'A'
       fincl1  = 'AOA1', 'AOA2', 'BR', 'BRCL', ...
       fincl2  = 'PS', 'Z3', 'T', 'U', 'V', ...
       fincl3  = 'PS:B', 'T:B', 'Z3:B', 'U:B', 'V:B', ...
       fincl4  = 'PS', 'PSL', 'U', 'V', 'T', ...
       fincl5  = 'MSKtem', 'PS', 'PSL', 'VTH2d', ...
       mfilt   = 1,365,30,120,240
       nhtfrq  = 0,-24,-24,-6,-3
```

- avgflag_pertape: averaging flag for all variables on history files (h0, h1, h2, etc.). Valid values are "`A`" (Average), "`I`" (Instantaneous), "`X`" (Maximum), "`M`" (Minimum), and "`B`" (GMT 00:00:00 average).

- fincl1, fincl2, etc: list of variables added to default output on h0, h1, etc. Appended ":" sets averaging flag for the field.

- fexcl1, fexcl2, etc: list of variables excluded from default output on h0, h1, etc.

How do I change output of existing namelist variables?

```
&cam_inparm
       avgflag_pertape     = 'A', 'I',  'I', 'A', 'A'
       fincl1  = 'AOA1', 'AOA2', 'BR', 'BRCL', ...
       fincl2  = 'PS', 'Z3', 'T', 'U', 'V', ...
       fincl3  = 'PS:B', 'T:B', 'Z3:B', 'U:B', 'V:B', ...
       fincl4  = 'PS', 'PSL', 'U', 'V', 'T', ...
       fincl5  = 'MSKtem', 'PS', 'PSL', 'VTH2d', ...
       mfilt   = 1,365,30,120,240
       nhtfrq  = 0,-24,-24,-6,-3
```

- mfilt: maximum number of time samples written to h0, h1, etc.
- nhtfrq: write frequencies for history files in timesteps (if positive) or hours (if negative). The h0 files may be monthly averages if nhtfrq(1) = 0.

- To change output in a run that has already started, see CAM user guide FAQ.

Running with a new namelist

- For durable namelist changes, create a `user_nl_cam` file
  - contains modified cam namelist settings
  - place in `$CASEROOT`
  - Reconfigure the case to generate a new namelist:

```
> cd $CASEROOT
> configure -cleannamelist
> configure -case
```

- Check the newly generated namelist prior to build:

```
> cd $CASEROOT/CaseDocs
> less atm_in
```

```
&chem_inparm
 airpl_emis_file              = '/fis/cgd/cseg/csm/inputdata/atm/cam/chem/trop_mozart/emis/emiss
 clim_soilw_file              = '/fis/cgd/cseg/csm/inputdata/atm/cam/chem/trop_mozart/dvel/clim_
 depvel_lnd_file              = '/fis/cgd/cseg/csm/inputdata/atm/cam/chem/trop_mozart/dvel/regri
 electron_file          = '/fis/cgd/cseg/csm/inputdata/atm/waccm/phot/electron.dat'
 euvac_file             = '/fis/cgd/cseg/csm/inputdata/atm/waccm/phot/euvac.nc'
 euvacdat_file          = '/fis/cgd/cseg/csm/inputdata/atm/waccm/phot/euvac.dat'
 flbc_date              = 20000101
```

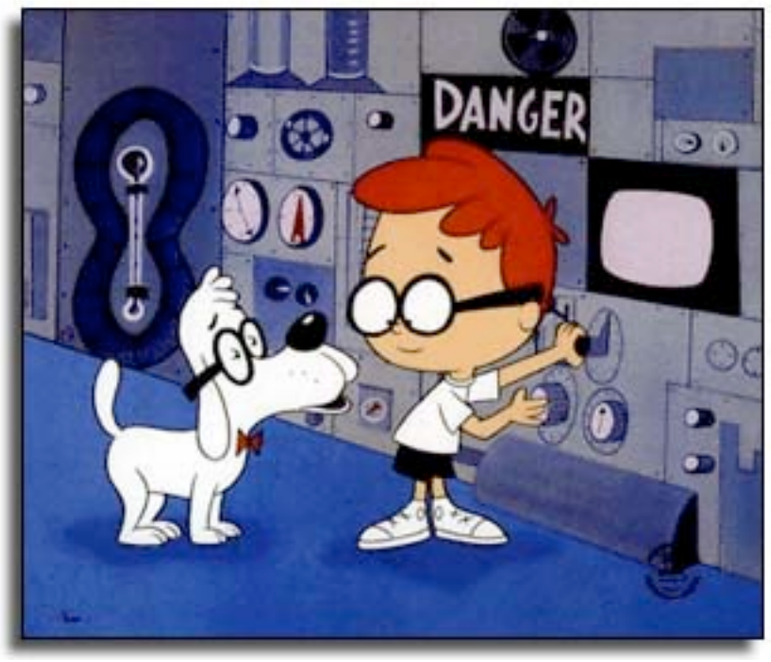
How do I create a new history variable?

- Modify source code to add calls to 2 routines governing history variables:
  - addfld: Add a field to the master field list. Called once at setup.
  - outfld: Accumulate (or take min, max, etc. as appropriate) input field into its history buffer for appropriate tapes. Called each timestep.
    - All modified routines go in `$CASEROOT/SourceMods/src.cam`
- Compile with modified source code:

```
> cd $CASEROOT
> $CASE.$MACH.build
```

How do I change a reaction rate?

- The **chemistry preprocessor**: generates CAM Fortran source code to solve chemistry.
- Input: a simple ASCII file listing chemical reactions and rates.
- Sample input files are in `$CCSMROOT/models/atm/cam/chem_proc/inputs`




```
 SPECIES
      Solution
O3, O, O1D -> O, O2, O2_1S -> O2, O2_1D -> O2
      End Solution

      Fixed
M, N2
      End Fixed
 End SPECIES

  Solution Classes
      Explicit
       CH4, N2O, CO, H2, CH3CL, CH3BR, CFC11, CFC12
      End explicit
      Implicit
       O3, O, O1D, O2, O2_1S, O2_1D
      End implicit
  End Solution Classes

  CHEMISTRY
      Photolysis
 [jo2_a] O2 + hv -> O + O1D
      End Photolysis

      Reactions
  [cph1,cph] O + O3 -> 2*O2       ; 8e-12, -2060
      End Reactions
END CHEMISTRY
```

Modifying the chemical preprocessor input file

- Temperature-independent rates: k [cm^3 $molec^{-1}$ s^{-1}]= a_0

```
O1D + H2O -> 2*OH                                    ; 2.2e-10
```

- Arrhenius type: k = a_0 * exp(b_0/T), where b_0 = (-E/R)

a_0, b_0

```
O + O3 -> 2*O2                                       ; 8e-12, -2060
```

- Troe rate constant: k = α^x / (1 - β^2), where:

$\alpha = k_0 * M / k_\infty$, $\beta = \log_{10}(\alpha)$, M= air density (molec cm^{-3}), T = temperature (K)

$k_0 = a_0 * (300/T)^{**} a_1$, $k_\infty = b_0 * (300/T)^{**} b_1$, x= "exponential factor"

```
[usr11] CH3CO3 + NO2 + M -> PAN + M ; 8.5e-29, 6.5, 1.1e-11, 1., .6
```

a_0, a_1, b_0, b_1, x

- User-specified reaction rate:

```
[usr1] O + O2 + M -> O3 + M
```

rate defined in routine `mo_usrrxt.F90`

Building the model with new chemistry

- Copy a sample preprocessor input file to the case directory and edit it:

```
> cd $CASEROOT
> cp $CCSMROOT/models/atm/cam/chem_proc/inputs/waccm3_57spc_JPL06_ccmval_clbrfam.in
my_waccm_mech.in
> nedit my_waccm_mech.in &
```

- Edit the file `env_conf.xml` in the case directory to add the CAM configure option `-usr_mech_infile` pointing to the new preprocessor input file:

```
<!--"CAM configure options, see CAM configure utility for details (char)" -->
<entry id="CAM_CONFIG_OPTS"   value="-phys cam4 -chem waccm_mozart
-usr_mech_infile $CASEROOT/my_waccm_mech.in"  />
```

- Reconfigure:

```
> configure -cleanall
> configure -case
```

How is the solar spectrum specified?

- Namelist variables point to 2 files specifying solar forcing
  - `solar_parms_file`: F10.7, K_p, A_p
    - solar and geomagnetic parameters used for aurora, UBCs, and wavelengths shorter than Lyman-α

```
> grep solar_parms_file CaseDocs/atm_in
 solar_parms_file = '/fis/cgd/cseg/csm/inputdata/atm/waccm/phot/wa_smax_c100517.nc'
```

  - `solar_data_file`: tsi, ssi, tsi_ref, ssi_ref
    - Covers wavelengths longer than Lyman-α
    - Time-variation of total solar irradiance, as well as variability with λ

```
> grep solar_data_file CaseDocs/atm_in
 solar_data_file = '/fis/cgd/cseg/csm/inputdata/atm/cam/solar/
spectral_irradiance_Lean_1610-2009_ann_c100405.nc'
```

- `solar_parms_file`: F10.7, K_p, A_p

```
> ncdump /fis/cgd/cseg/csm/inputdata/atm/waccm/phot/wa_smax_c100517.nc
netcdf wa_smax_c100517 {
dimensions:
        time = UNLIMITED ; // (2 currently)
variables:
        float f107(time) ;
                f107:long_name = "10.7 cm solar radio flux (F10.7)" ;
                f107:units = "10^-22 W m^-2 Hz^-1" ;
        float f107a(time) ;
                f107a:long_name = "81-day centered mean of 10.7 cm solar radio flux (F10.7)" ;
        float kp(time) ;
                kp:long_name = "Daily planetary K index" ;
        short ap(time) ;
                ap:long_name = "Daily planetary a index" ;
                ap:units = "nanoTeslas" ;
        short isn(time) ;
                isn:long_name = "International Sunspot Number" ;
        int date(time) ;
                date:long_name = "current date (YYYYMMDD)" ;
data:
 f107 = 210, 210 ;
 f107a = 210, 210 ;
 kp = 4, 4 ;
 ap = 27, 27 ;
 isn = 0, 0 ;
 date = 101, 22000101 ;
}
```

List of dates between which other data are interpolated

- `solar_data_file`: tsi, ssi, tsi_ref, ssi_ref

- Data are given as a function of time (i.e. annually or daily) and wavelength
- tsi (time): total solar irradiance (W m^{-2})
- ssi (time, wavelength): solar spectral irradiance (mW m^{-2} nm^{-1})
- tsi_ref, ssi_ref: values for tsi and ssi averaged over the reference time period of years 1834-1867 (solar cycles 8-10).

```
netcdf spectral_irradiance_Lean_1610-2009_ann_c100405 {
dimensions:
        time = UNLIMITED ; // (400 currently)
        ref_time_bound = 2 ;
        wavelength = 3780 ;
variables:
        double tsi_ref ;
                tsi_ref:time_op = "average" ;
                tsi_ref:bounds = "ref_time_bound" ;
                tsi_ref:long_name = "average of tsi over ref_time_bound
                tsi_ref:units = "W/m^2" ;
                tsi_ref:average_op_ncl = "dim_avg over dimension: time"
        double ref_time_bound(ref_time_bound) ;
                ref_time_bound:units = "days since 0000-01-01 00:00:00"
                ref_time_bound:long_name = "reference time interval bou
        int date(time) ;
                date:format = "YYYYMMDD" ;
        double time(time) ;
                time:calendar = "noleap" ;
                time:axis = "T" ;
                time:time_origin = "01-JAN-0000" ;
                time:units = "days since 0000-01-01 00:00:00" ;
        double wavelength(wavelength) ;
                wavelength:units = "nm" ;
                wavelength:long_name = "Wavelength of band center" ;
        double band_width(wavelength) ;
                band_width:units = "nm" ;
                band_width:long_name = "Wavelength width of band" ;
        double ssi_ref(wavelength) ;
                ssi_ref:time_op = "average" ;
                ssi_ref:bounds = "ref_time_bound" ;
                ssi_ref:long_name = "average of ssi over ref_time_bound
                ssi_ref:units = "mW/m^2/nm" ;
                ssi_ref:average_op_ncl = "dim_avg over dimension: time"
        double tsi(time) ;
                tsi:units = "W/m^2" ;
                tsi:long_name = "Total Solar Irradiance at 1 a.u." ;
        double ssi(time, wavelength) ;
                ssi:units = "mW/m^2/nm" ;
                ssi:long_name = "Solar Spectral Irradiance at 1 a.u." ;
```

How do I change a boundary condition?

- Find an existing boundary condition file (LBC or UBC):

```
> grep lbc CaseDocs/atm_in
 flbc_date = 20000101
 flbc_file = '/path/to/inputdata/atm/waccm/lb/LBC_1765-2005_1.9x2.5.nc'
 flbc_list = 'N2O', 'HCFC22', 'H2', 'CO2', 'CH4', 'CH3CL', 'CH3CCL3', ...
 flbc_type = 'CYCLICAL'
> cd /path/to/inputdata/atm/waccm/lb
```

- Modify the existing netCDF BC data file (via NCL, NCO, IDL) to produce a new one:

```
> ncap -O  -s "CO2=CO2*0.833"  $infile $outfile

> ncatted -a units,CO2,o,c,"kg/kg" $outfile
```

- Change `flbc_file` or the appropriate `ubc_file` in your namelist to point your new file

How do I change an initial condition?

- Copy an existing initial condition file:

```
> grep ncdata CaseDocs/atm_in
 ncdata='/path/to/inputdata/atm/waccm/ic/icfile.cam2.i.2000-01-01-00000.nc'

> cd /path/to/inputdata/atm/waccm/ic
```

- Modify the existing netCDF input data file (via NCL, NCO, IDL) to produce a new one:

```
> ncap -O  -s "CO2=CO2*0.833"  $infile $outfile

> ncatted -a units,CO2,o,c,"kg/kg" $outfile
```

- Change `nc_data` in your namelist to point your new file
- Run as an initial run

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