User's Guide for CASA2WRF

Jossy P. Jacob, Zhining Tao and Eric Kemp

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1 Overview

Coupled NU-WRF-CASA modeling system has the capability for tracer CO_2 (i.e., no interaction with chemistry) simulations. It is expected to resolve small scale CO_2 sources and sinks, reduce transport uncertainties, and contribute to improving global CO_2 modeling. This requires specifying initial, lateral boundary, and flux emission fields of CO_2. To that end, several utilities have been developed to process the Carnegie-Ames-Stanford-Approach (CASA) global CO_2 concentrations and fluxes and provide them to NU-WRF.

CASA CO_2 concentrations are based on the Goddard Space Flight Center Parameterized Chemistry and Transport Model (PCTM), which is driven by the real-time meteorological fields from the Goddard Global Modeling and Assimilation Office, version 5 (GEOS-5). The biospheric CO_2 fluxes are produced from CASA, the biomass burning emissions are from the Global Fire Emissions Database (GFED), and the oceanic and anthropogenic CO_2 fluxes are based on the sources described by Kawa et al.[2004, 2010]. The hourly model output is at the resolution of 1 x 1.25 degree with 28 vertical levels. The PCTM/GEOS5/CASA-GFED model has been widely tested, and has shown favorable results in carbon cycle comparison studies [e.g., Kawa et al., 2010, and references therein].

CASA2WRF is the NU-WRF utility for preprocessing the CO_2 concentration and flux data to provide initial and boundary conditions to WRF. It reads the CASA CO_2 concentration in the NETCDF format, interpolates it to WRF domains (single or nested), and appends variable casaco2 to wrfinput and wrfbdy files at given time intervals.. Additionally, CASA2WRF utility reads the CO_2 flux data, interpolate them to WRF domains (single or nested), and write to NETCDF files readable to NU-WRF with a frequency specified in the WRF namelist file. The capability to interpolate the flux data at each simulation time step in NU-WRF is achieved by adding the flux tendency (rate of flux change) to the flux data files.

A second pre-processing capability is added to the CASA2WRF utility in which the temporal interpolation of CASACO2 flux is depending on the NU-WRF model state. This option is initiated by a namelist option "flux_interpolate". With this option, the NU-WRF model state is read by the casa2wrf every hour and wrf-domain interpolated CO_2 flux components from 6 different sources - Respiratory (monthly), Net Production (monthly), Bio-fuel (monthly), Fossil Fuel (yearly), Wild fire (daily) and Ocean CO_2 are combined to produce a total flux and flux tendency netcdf files to input to NU-WRF WRFCHEM runs.

2 Using the Software

To compile CASA2WRF, the user must type **./build.sh casa2wrf** or **./build.sh allchem** and executables for pre-processing CASA CO_2 data and casa2wrf will be created. The workflow for using CASACO2 is listed below.

1. Run GEOGRID

2. Run UNGRIB (or MERRA2WRF or GEOS2WRF)
3. Run METGRID
4. Run REAL
5. Run CASA2WRF
6. Run WRF-Chem with CASA option

There are 4 steps for including CASACO2 in NU-WRF.

2.1 Compile CASA2WRF and pre-processors

Compile: **NUWRFDIR/build.sh casa2wrf**. It creates the following executables in NUWRFDIR/utils/casa2wrf/.

- /pproc/Read_CO2_conc.x - To pre-process the CO2 concentration data file to netcdf data file.
- /pproc/Read_CO2_Flux.x - To pre-process the CO2 Flux data file to netcdf data files.
- /pproc1/ConvertData2Netcdf.x - To pre-process the CO2 flux component files in binary format to netcdf data files.
- /bin/casa2wrf - To process the CO2 concentration and Flux data to wrfinput, wrfbdy and flux input files for WRFCHEM runs.

2.2 CASACO2 pre-processor

Pre-processor for CASA2WRF ($NUWRFDIR/utils/casa2wrf/pproc/) converts the binary input files from PCTM to NETCDF format and add a timestamp in the WRF time format.

- CO_2 Concentration data: Compile with ./build.sh casa2wrf or to compile separately: make Makefile_CO2_conc (or compile with NUWRF build.sh casa2wrf) and to run: ./Read_CO2_conc.x filename indir; creates netcdf files in conc/CASACO2.*.nc
- CO_2 flux data: Compile with NUWRF build.sh casa2wrf or to compile separately: make -f Makefile_CO2_Flux and to run: Read_CO2_Flux.x filename indir ; creates yearly NETCDF data file: flux/CO2flux *.nc
- CO_2 Flux data interpolation with NU-WRF state: Compile with ./build.sh casa2wrf or to compile separately: make Makefile_convert (or compile with NUWRF build.sh casa2wrf) and to run: Input Binary data should be in subdirectory: Binary/ and output will be created in Netcdf_data/ directory by running the executable: ./ConvertData2Netcdf.x.

2.3 Run CASA2WRF

- Compile: **./build.sh casa2wrf**
- Run: ./casa2wrf or use batch scripts: run_casa2wrf_discover.sh.
- Make sure that the wrfinput_d* and wrfbdy_d01 exists in your rundir.
- Output: wrfinput and wrfbdy files will be modified, and flux datafiles will be generated in chem_flux/ directory.

The **namelist.casa2wrf** contains the following information:

Variable Names	Description
&wrf	
max_dom	integer, specifies number of domains.
wrf_dir	string, WRF run directory
flux_only	integer, =0 for processing CO2 concentration and flux data, =1 for processing CO2flux2 flux emission data only.
flux_interpolate	integer, =1 for interpolate with NU-WRF state, =0 do not use temporal interpolation with NU-WRF state.
fluxdt	real, time interval of input flux emission data in hours.
&casa_conc	
casa_format	integer, =5 for netcdf files
casa_dir	string, CASACO2 concentration data directory
casa_prefix	string, CASACO2 concentration datafile prefix
&casa_flux	
casa_format	integer, =5 for netcdf files
casa_dir	string, CASACO2 flux emission data directory
casa_prefix	string, CASACO2 flux datafile prefix

The fortran code (src/casa_flux_filenames_mod.f90 contains the information about the filenames for flux components.

Variable Names	Description
NUM_FLUX_VARIABLES = 6	number of FLUX variables
NPPname = 'NPP0_2010_mon0.nc'	NPP filename
FIREname = 'FIRE_2010_daily_01.nc'	Fire emission filename
RESPname = 'RESP_2010_mon0.nc'	Respiratory Filename
BFUELname = 'BFUE_2010_mon0.nc'	Bio-Fuel filename
OceanCO2name = 'OCO2_2010_mon0.nc'	Ocean CO_2 filename
FossilFuelname = 'FFUE_2010_year.nc'	Fossil Fuel filename
flux_conversion_factors = /1.0,1.0,1.0,1.0,1.0,1.0/	Conversion Factors
qclimit = /20.0,60.0, -95.0, -60.0/	QC latitude and longintude limits

2.4 Run WRFCHEM

To run WRF-Chem with CASACO2, the **namelist.input** file should have the following information:

Variable Names	Description
&time_control	
auxinput18_inname	string, = "chem_flux/CO2_(domain)_(date)", flux datafile name
auxinput18_interval_m	integer, time interval of input flux data in minutes for each domain e.g. for 3 hourly input data = 180,180,
FRAMES_PER_auxinput18	integer, number of dataset in each datafile e.g. for 1 data set in each file/ 2 domains = 1,1
IO_FORM_HISTORY	integer, = 2, for netcdf file
IO_FORM_RESTART	integer, = 2, for netcdf file
IO_FORM_INPUT	integer, = 2, for netcdf input file
IO_FORM_BOUNDARY	integer, = 2, for netcdf file
io_form_auxinput18	integer, = 2, for netcdf input file
&chem	
chem_opt	integer, for casaco2, chem_opt for each domain =18, 18,
io_style_emissions	integer, emission input file format = 2 for netcdf
casafxdt	emission data interval in minutes for each domain, e.g. for 3 hourly files casafxdt = 180., 180.,
emiss_inpt_opt	integer, for casaco2 case = 18, 18,
emiss_opt	integer, for casaco2 case = 18, 18,
chem_in_opt	integer, = 1, 1,
emi_inname	string, emission input filename, e.g. = "chem_flux/CO2_"
emiss_opt_vol	integer, = 0,0,
phot_opt	integer, = 2, 2,
gas_drydep_opt	integer, = 0, 0,
gas_bc_opt	integer, for casaco2 case = 18, 18,
gas_ic_opt	integer, for casaco2 case = 18, 18,
have_bcs_chem	logical, Lateral boundary condition is provided for outer domain only e.g. = .true., .false.,

3 References

Kawa, S. R., D. J. Erickson III, S. Pawson, and Z. Zhu (2004), Global CO2 transport simulations using meteorological data from the NASA data assimilation system, J. Geophys. Res.,109, D18312, doi:10.1029/2004JD004554.

Kawa, S. R., J. Mao, J. B. Abshire, G. J. Collatz, X. Sun, and C. J. Weaver (2010), Simulation studies for a space-based CO2 lidar mission, Tellus, Ser. B, 62 (5), 759 ? 769, doi:10.1111/j.1600-0889.2010.00486.x