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Testing of WRF-GHG on simulation of atmospheric methane in Yangtze River Delta region

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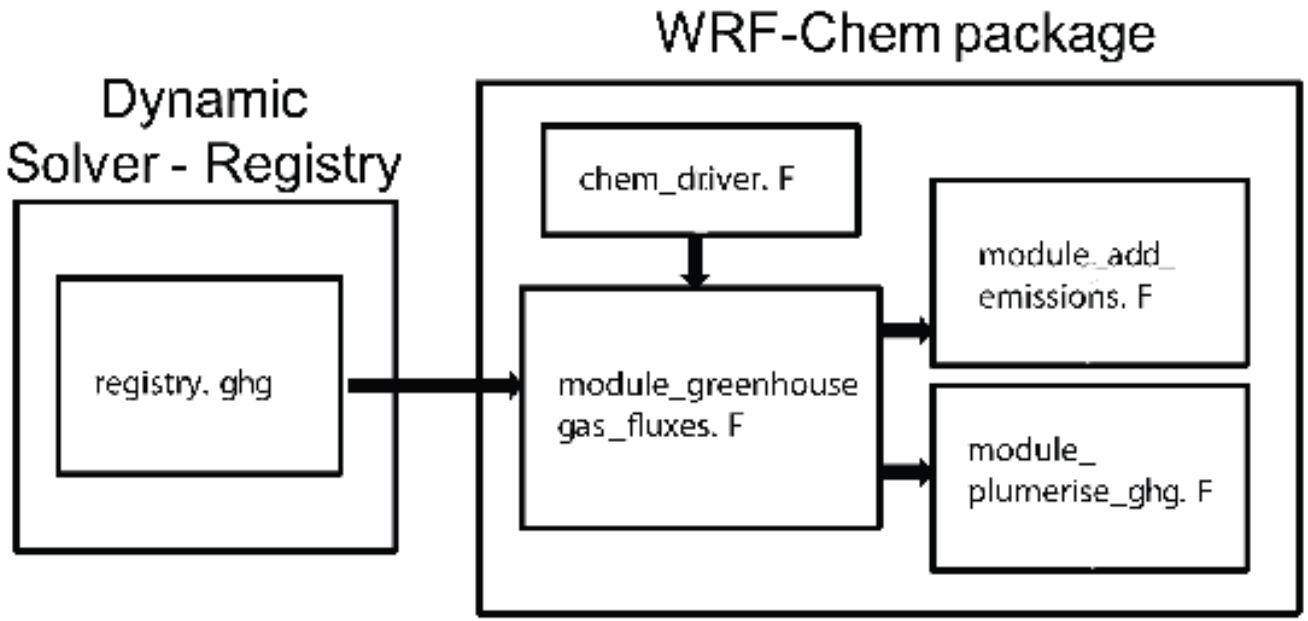
Outline

- Brief description of WRF-GHG
- A case study
- Next steps

Coupling GHG with WRF/Chem



Four additional modules are added to WRF-Chem and some minor modifications required by WRF-Chem itself.

From Diao's presentation

Registry.ghg

CH4_1	total atmospheric CH_4 concentration
CH4_2	changes in CH_4 concentration from wetland emissions
CH4_3	changes in CH_4 concentration from anthropogenic emissions
CH4_4	changes in CH_4 concentration from biomass burning
CH4_5	changes in CH_4 concentration from termite emissions
CH4_6	changes in CH_4 concentration from soil uptake
CH4_7	changes in CH_4 concentration from vegetation
CH4_B	atmospheric CH_4 background concentration

CH_4 variables defined in WRF/GHG

CH_4		
fl_wet	ext. wetland	hourly [30]
fl_ant4	ext. anthropogenic	daily [1]
fl_antch4	ext. anthropogenic	hourly [30]
fl_bbch4	ext. biomass burning	daily [1]
bb_ch4	3d int. biomass burning	WRF timestep
fl_term	ext. termite emission	daily [1]
fl_soilu	ext. soil uptake	hourly [30]
fl_veg	ext. vegetation	hourly [30]
ch4_emiss	int. wetland	WRF timestep
ch4_term	int. termite emission	WRF timestep
ch4_soil	int. soil uptake	WRF timestep
ch4_veg	int. vegetation	WRF timestep

CH_4 flux variables defined in WRF/GHG

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Linkage of emission with CH_4 concentration

- co2_surface_source_add
- co2_surface_source_ad2
- add_emis_anthro_ghg
- add_emis_burn_ghg

Follow the same principle

$$chem(i,1,j) = chem\_source(i,j)\left[\frac{kg}{m^2 s}\right] \times conv\_rho(i,1,j)\left[\frac{sm^2}{kg}\right]$$

$$conv\_rho(i,1,j) = \frac{1}{rho(i,1,j)[\frac{kg}{m^3}]} \times \frac{dt[s]}{dz8(i,1,j)[m]}.$$

Here $rho(i,1,j)$ denotes the air density in the first model layer, dt the time step of the model and $dz8(i,1,j)$ the thickness of the first model layer in [m].

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Calculation of CH_4 fluxes

- Online calculation of CH_4 wetland flux
- Flux from termite
- Flux from soil uptake
- Flux from vegetation
- Flux from biomass burning

Kaplan online calculation of CH_4 flux

- **Inputs**
  - C_pool (external carbon pool, LPJ model [sitch et al.,2003])
  - Wetland_map (Kaplan potential wetland map, wetland fraction/grid)
  - Soil parameters (T_soil, Soil _type; Soil_M, etc.)
- **Outputs**
  - CH_4_wet (CH_4 wetland emission)

$$k_r = \frac{\frac{1}{\tau_0} \cdot g(T) \cdot f_{SM}}{12 \cdot 24 \cdot 30}.$$

$$f_{SM} = 0.25 + 0.75 \frac{sm}{sm_{sat}}$$

$$g(T) = \exp\left(308.56 \cdot \left(\frac{1}{56.02} - \frac{1}{T + 46.01}\right)\right)$$

```
  g_T(i,j) = EXP(308.56*(1.0/56.02 - 1.0/(T_2s(i,j) + 46.02)))
  f_SM(i,j) = 0.25 + 0.75 * (sm_tot(i,j)/soil_sat(i,j))
  k_r(i,j) = ((1/tau_10)*g_T(i,j)*f_SM(i,j))/(12.0*24.0*30.0)
  Carbon(i,j) = C_pool(i,j)*(1.0 - EXP(-k_r(i,j)*1.0))
  Carbon(i,j) = Carbon(i,j)/(3600.0)
  HR(i,j) = 0.7*Carbon(i,j)
T_flood(i,j) = HR(i,j)*M_s*Wet_map(i,j)
T_peat(i,j) = HR(i,j)*E_f*Wet_map(i,j)
IF(wet_id == 2) then
  CH4_wet(i,j) = T_flood(i,j)
ELSE IF(wet_id == 3) then
  CH4_wet(i,j) = T_peat(i,j)
ELSE IF(wet_id == 1) then
P_1(i,j) = EXP((T_a(i,j) - 303.0)/8.0)
```

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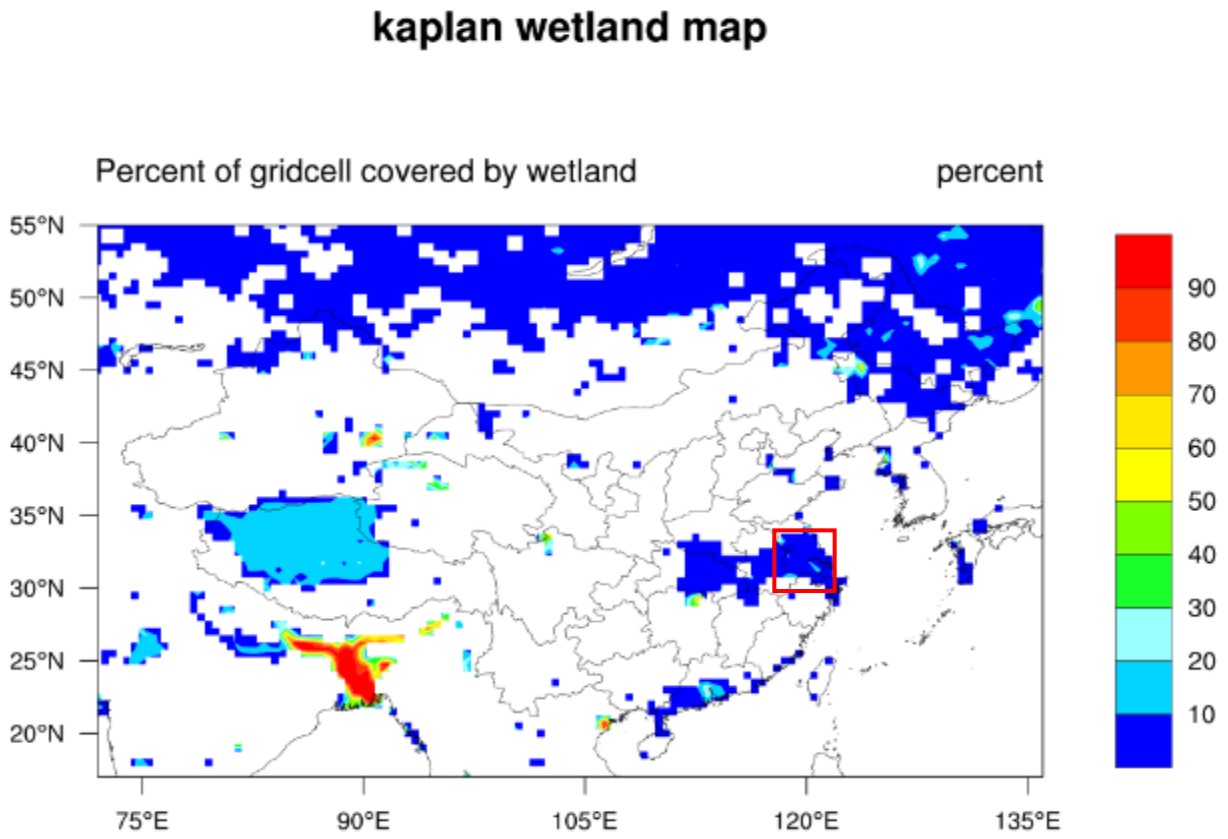
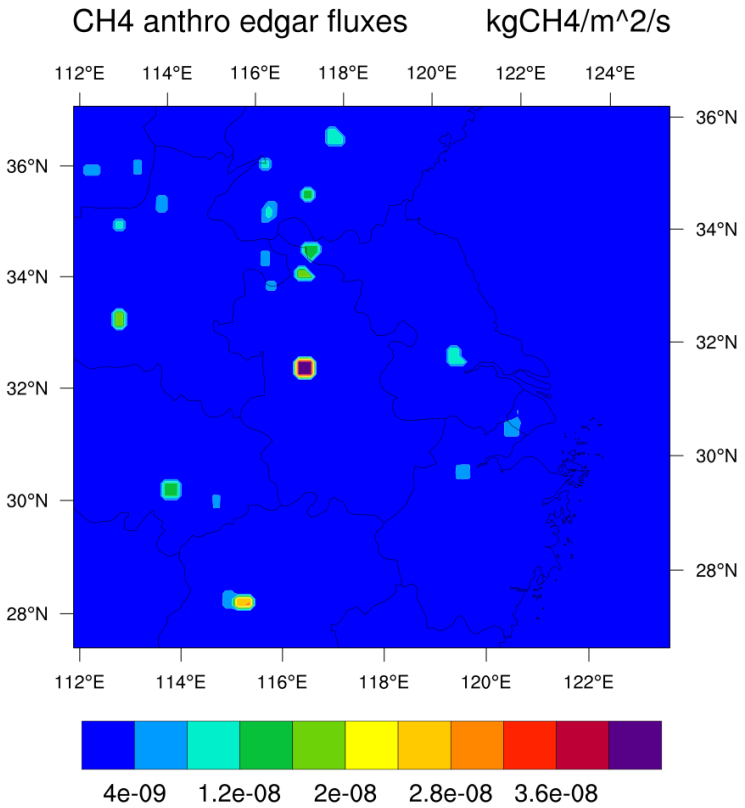
Kaplan online calculation of CH_4 flux (cont.)



From *http://arve.epfl.ch/pub/wetlands/index.html*

Anthropogenic emissions of CH_4

- Emission inventory: EDGAR V4 (http://edgar.jrc.ec.europa.eu)
- Resolution: 0.1° ×0.1°
- Base year: 2005
- Processing code: Prep_chem_source (a diurnal cycle peaking twice a day at 08:00 and 20:00 local time using a double Gaussian function are included here)



Kaplan module implemented in GHG

Take “CH4_2” for example

In the namelist.input

chem_opt	98
wetland_type	
0	no CH_4 wetland emissions
1	floodplain and peatland CH_4 wetland emissions (Kaplan)
2	only floodplain CH_4 wetland emissions (Kaplan)
3	only peatland CH_4 wetland emissions (Kaplan)
4	external CH_4 wetland emissions (Walter)

In chem_driver.F

```
IF ( config_flags%chem_opt==98 ) THEN
   call greenhouse_gases  (   chem, num_3d_c, grid%alt, dz8w, grid%dt, grid%xtime,      &
                              ids,ide, jds,jde, kds,kde,                                &
                              ims,ime, jms,jme, kms,kme,                                &
                              its,ite, jts,jte, kts,kte,                                &
                              config_flags%run_hours, config_flags%co2_anthro,          &
```

Module_greenhouse_gases

SELECT CASE(wet_id)

CASE(1)

call KAPLAN

call co2_surface_source_add(…)

……

CASE(4)

chem_sourcewet(:,:)=fl_wet(:,:)

……

WRITE(6,*) ‘wetland walter was called’

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Initial and boundary conditions

- Meteorology: NCEP FNL or ECMWF reanalysis data.
- CH_4 and CO_2: three-dimensional fields from global transport models TM5.
- The meteorology is initialized with ECMWF fields, while the tracer variables are initialized with outputs of global chemistry models like MOZART, TM5, or GOES-Chem on the first run and the simulations on the following runs are initialized with the previous day results to ensure continuity.

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Steps to run WRF-GHG

- Compile source codes, WRF-GHG and WPS
- Run WPS to process all necessary fields on the predefined WRF grid
- Modify the namelist.input
- Run real.exe
- Use Matalab scripts process ICs/BCs of chemical species
- Run wrf.exe

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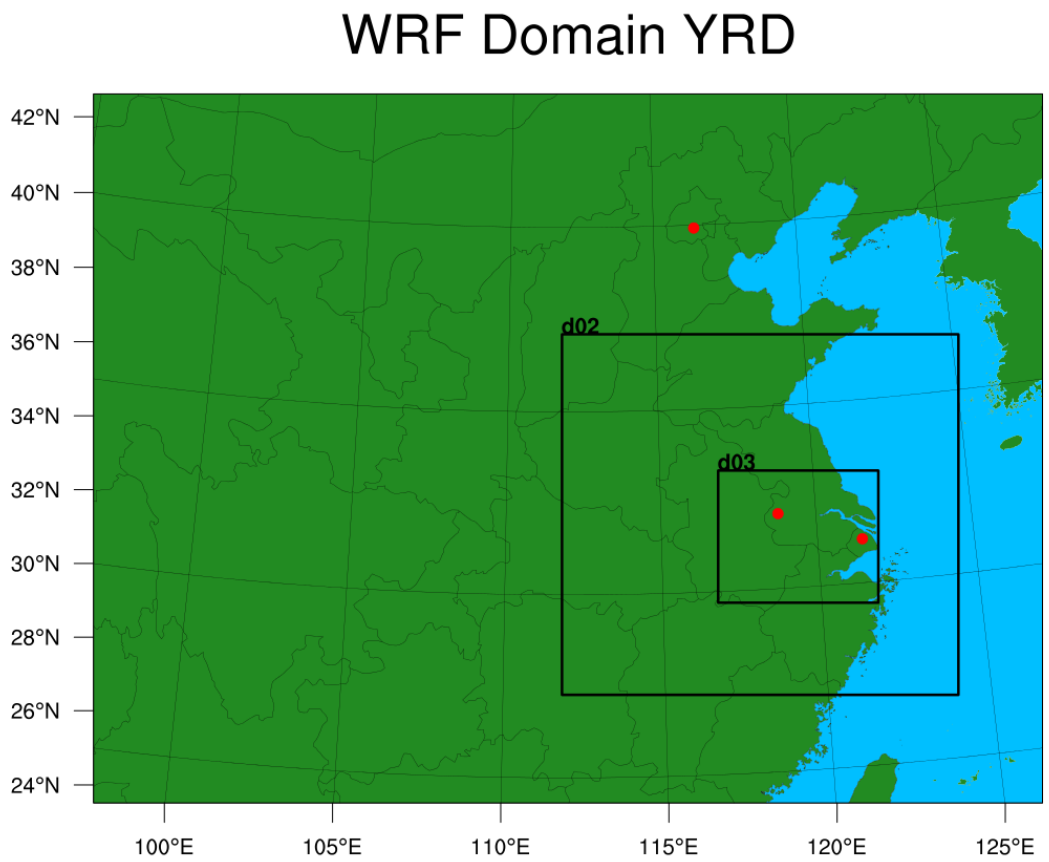
Three-nested domains



d1:36km

d2:12km

d3:4km

Vertical levels:40

Namelist setting

```
vprm_class                      = 8,
vprm_par_file                   = "VPRM_param_CERES2005_local.txt",
co2_st_time                     = 0,
co2_anthro                      = 2,

wetland_type                    = 0,

file_term                       = "CH4_termite_NW.txt",
term_id                         = 0,

bb_opt_ghg                      = 0,
plume_frq_ghg                   = 180,

soil_id                         = 1,

veg_id                          = 1,

oce_id                          = 0,


chem_opt                98

vertmix_onoff           1
have_bcs_chem           .true.

chem_in_opt             0
emiss_inpt_opt          0
chem_conv_tr            1
```

hourly anthropogenic emissions

no CH4 wetland emissions

Calculation of soil uptake fluxes

Calculation of CH4 emissions from vegetation

to allow for vertical mixing of the tracer

to allow for subgrid convective tracer transport

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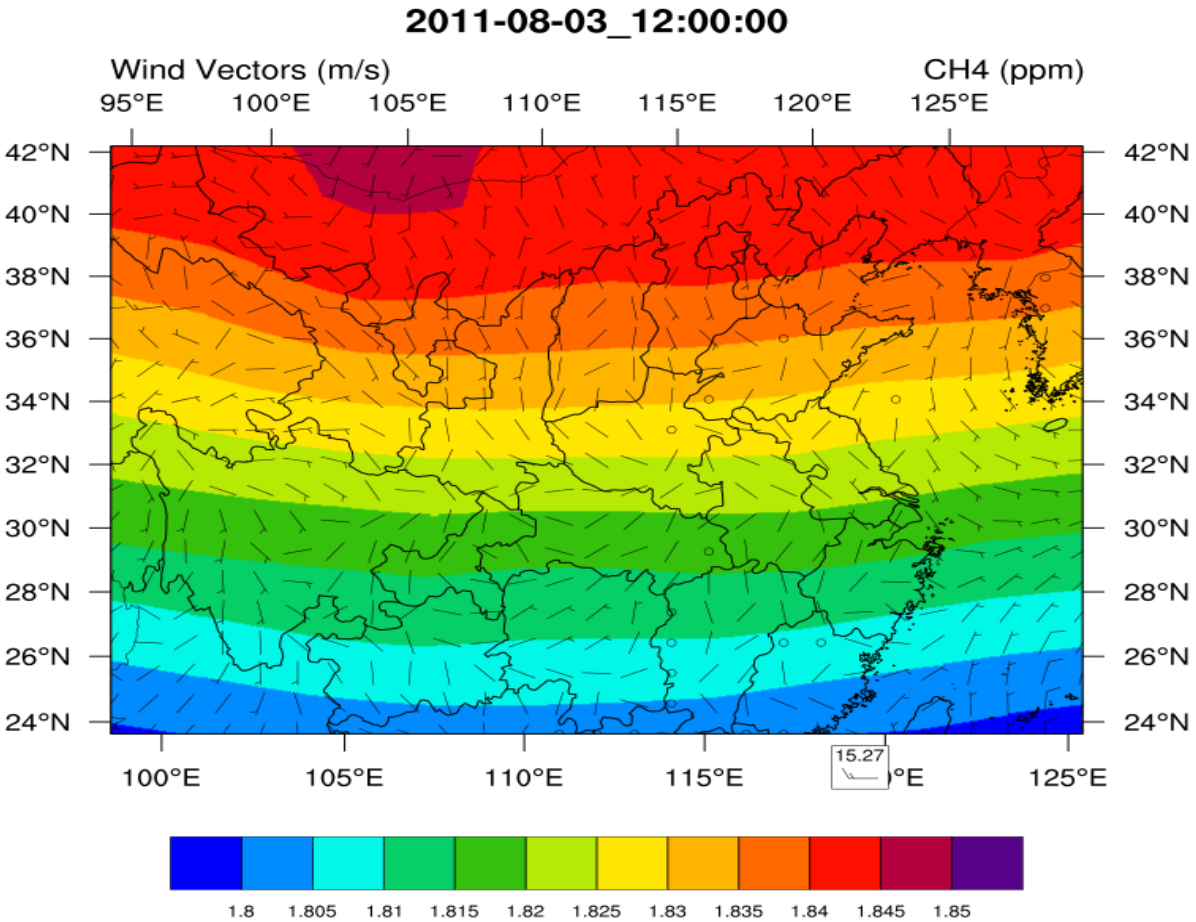
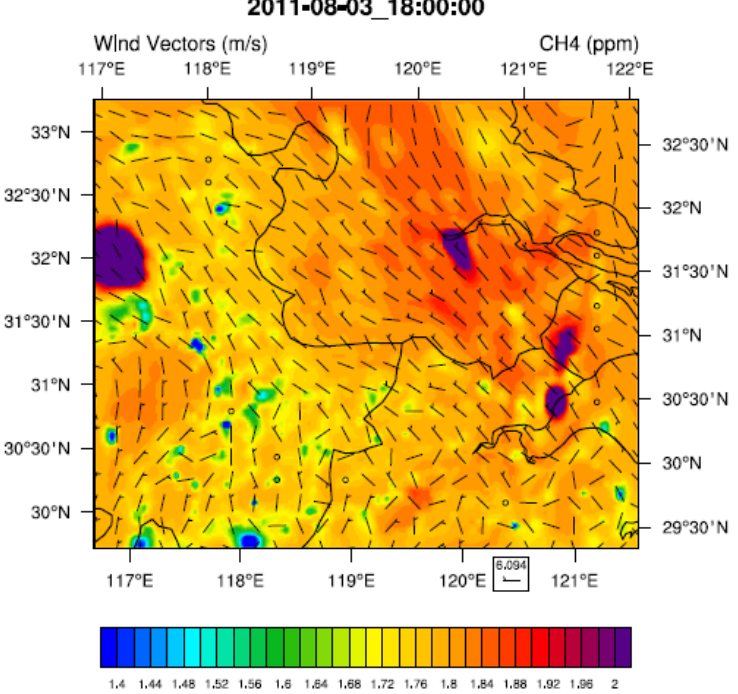
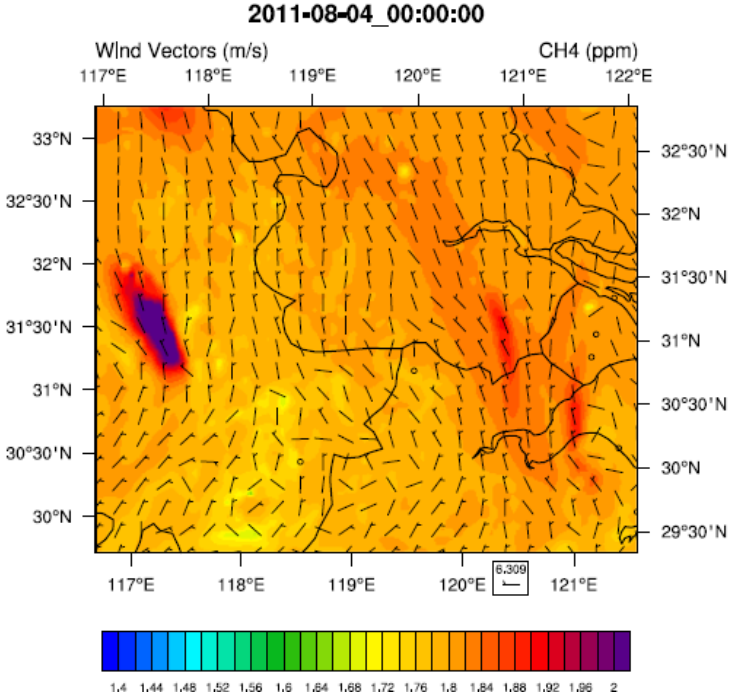
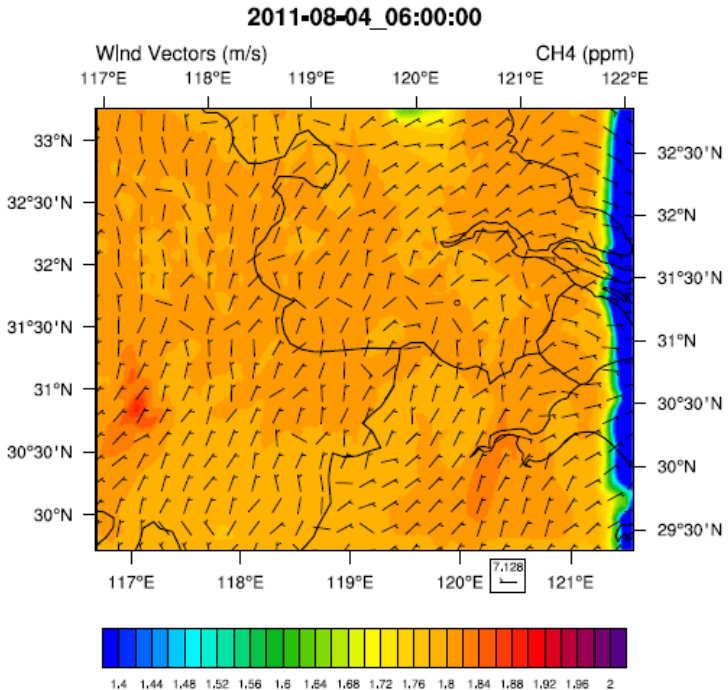
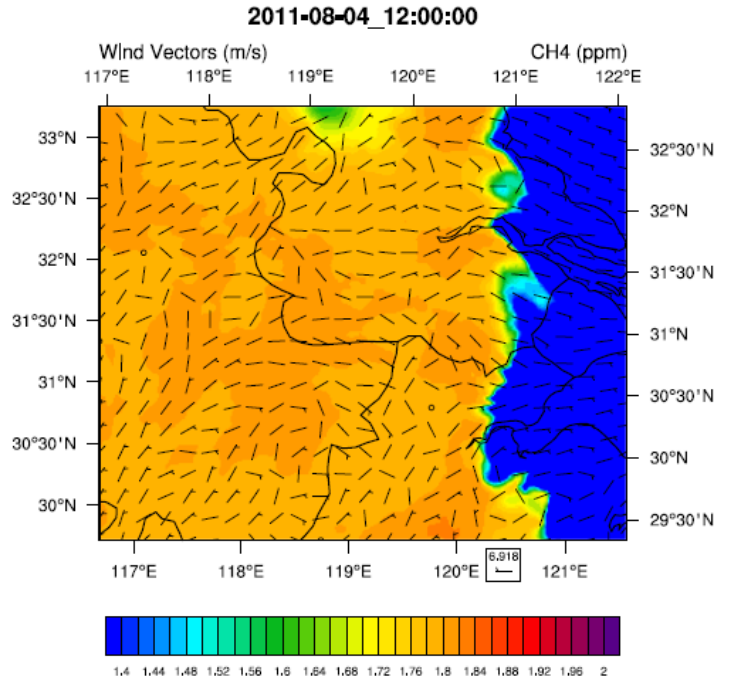
Case Study: Simulated CH_4




2011-08-03_18:00:00
Wind Vectors (m/s)
CH4 (ppm)
117°E 118°E 119°E 120°E 121°E 122°E
33°N 32°30'N 32°N 31°30'N 31°N 30°30'N 30°N
32°30'N 32°N 31°30'N 31°N 30°30'N 30°N 29°30'N
6.094
1.4 1.44 1.48 1.52 1.56 1.6 1.64 1.68 1.72 1.76 1.8 1.84 1.88 1.92 1.96 2


2011-08-04_00:00:00
Wind Vectors (m/s)
CH4 (ppm)
117°E 118°E 119°E 120°E 121°E 122°E
33°N 32°30'N 32°N 31°30'N 31°N 30°30'N 30°N
32°30'N 32°N 31°30'N 31°N 30°30'N 30°N 29°30'N
6.309
1.4 1.44 1.48 1.52 1.56 1.6 1.64 1.68 1.72 1.76 1.8 1.84 1.88 1.92 1.96 2


2011-08-04_06:00:00
Wind Vectors (m/s)
CH4 (ppm)
117°E 118°E 119°E 120°E 121°E 122°E
33°N 32°30'N 32°N 31°30'N 31°N 30°30'N 30°N
32°30'N 32°N 31°30'N 31°N 30°30'N 30°N 29°30'N
7.128
1.4 1.44 1.48 1.52 1.56 1.6 1.64 1.68 1.72 1.76 1.8 1.84 1.88 1.92 1.96 2


2011-08-04_12:00:00
Wind Vectors (m/s)
CH4 (ppm)
117°E 118°E 119°E 120°E 121°E 122°E
33°N 32°30'N 32°N 31°30'N 31°N 30°30'N 30°N
32°30'N 32°N 31°30'N 31°N 30°30'N 30°N 29°30'N
6.918
1.4 1.44 1.48 1.52 1.56 1.6 1.64 1.68 1.72 1.76 1.8 1.84 1.88 1.92 1.96 2

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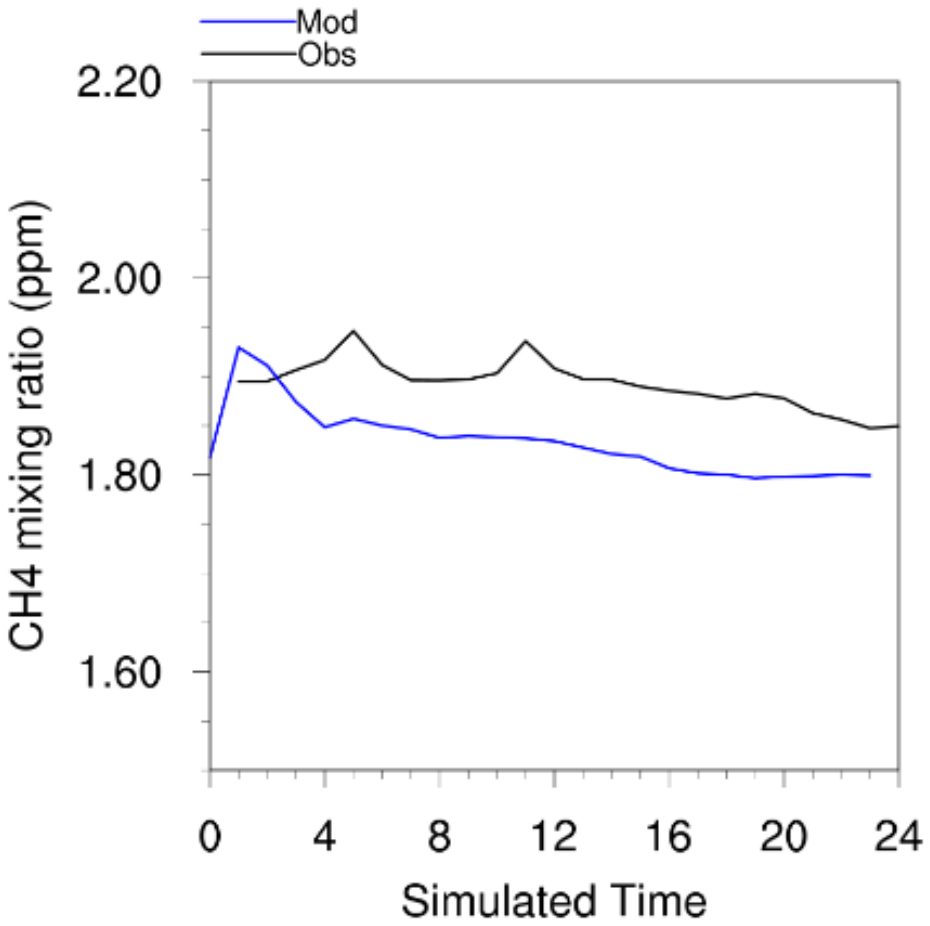
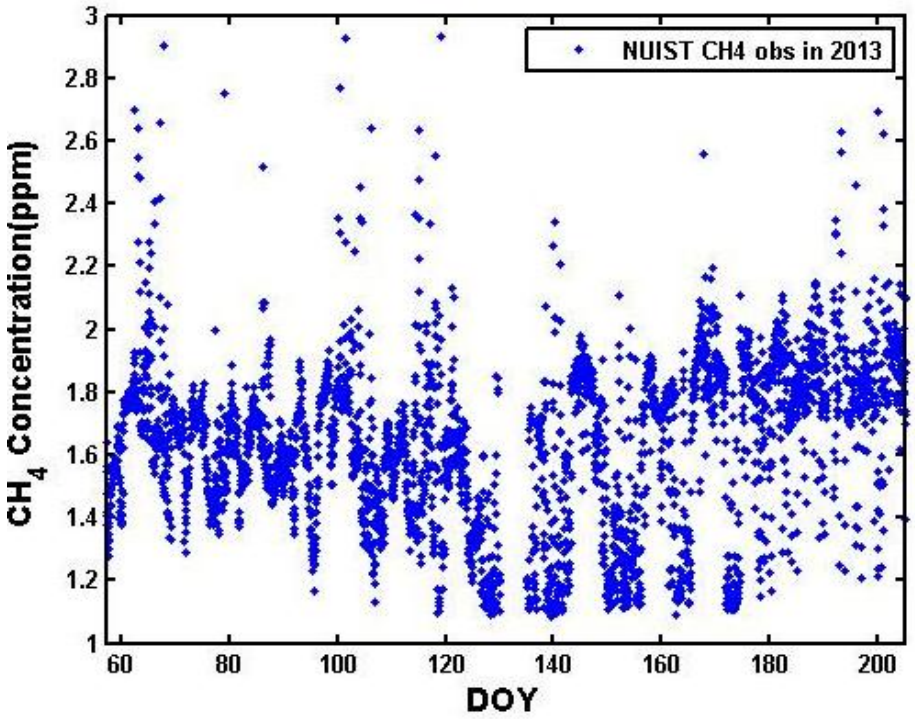
Comparison of simulated CH_4 with observed in MLW

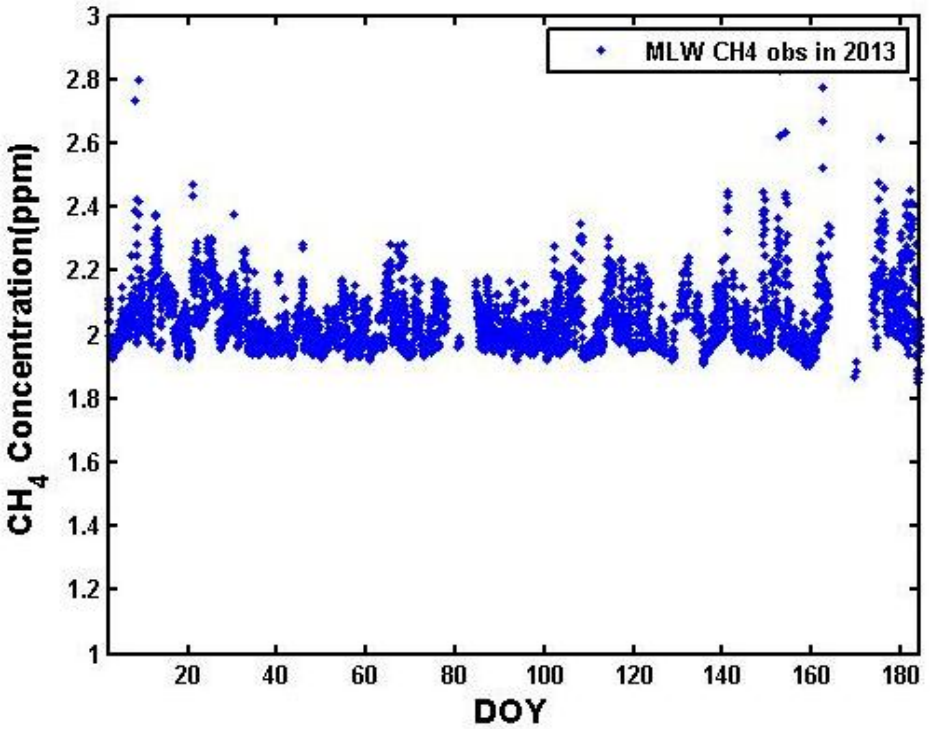


Obs data is 2012.08.03-08.04

Mod data is 2011.08.03-08.04

CH_4 observed at NUIST and MLW





CH_4 concentration in NUIST is lower than that at MLW.

The diurnal pattern of CH_4 is not as obvious as CO_2.

Summary and future work

- Able to reproduce a case for WRF/GHG simulation on CH_4 using the available IC/BC and emission input files

- Will revisit all input parameters used in Kaplan to find a best scenario for application in Yangtze River Delta region (from a box model to a three dimensional model, WRF/GHG)

- Will learn how to generate emission, initial and boundary conditions of CH_4 and other chemical species for a new case.

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Thank You!