Impact of 2019 mid-west flood on CO_2 and CH_4 using yearly WRF-GHG simulations over the contiguous United States

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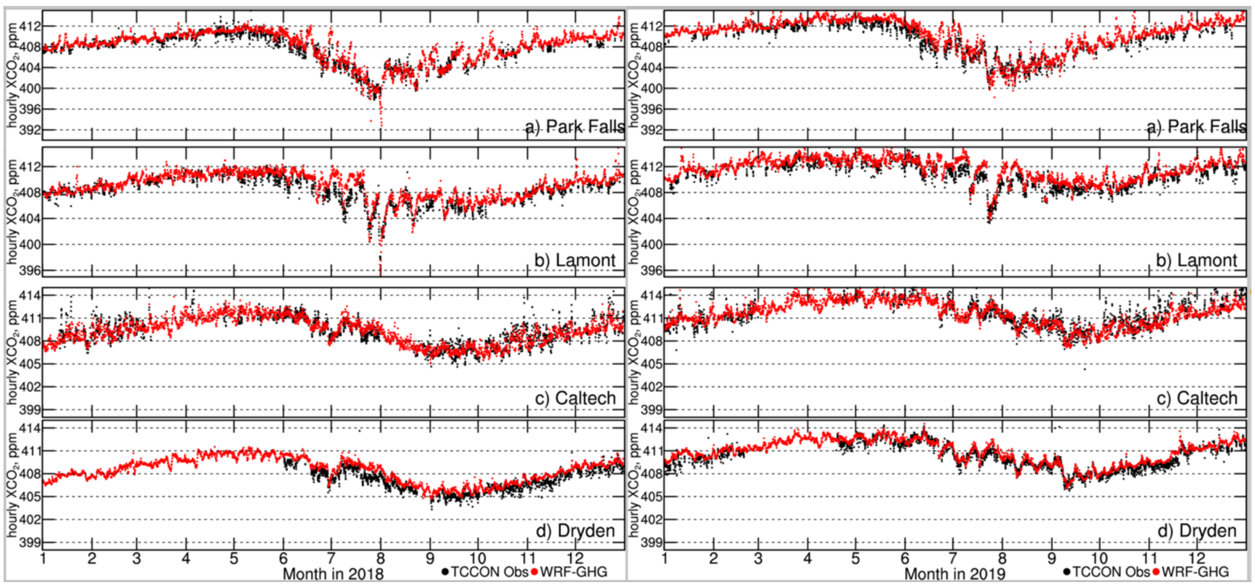
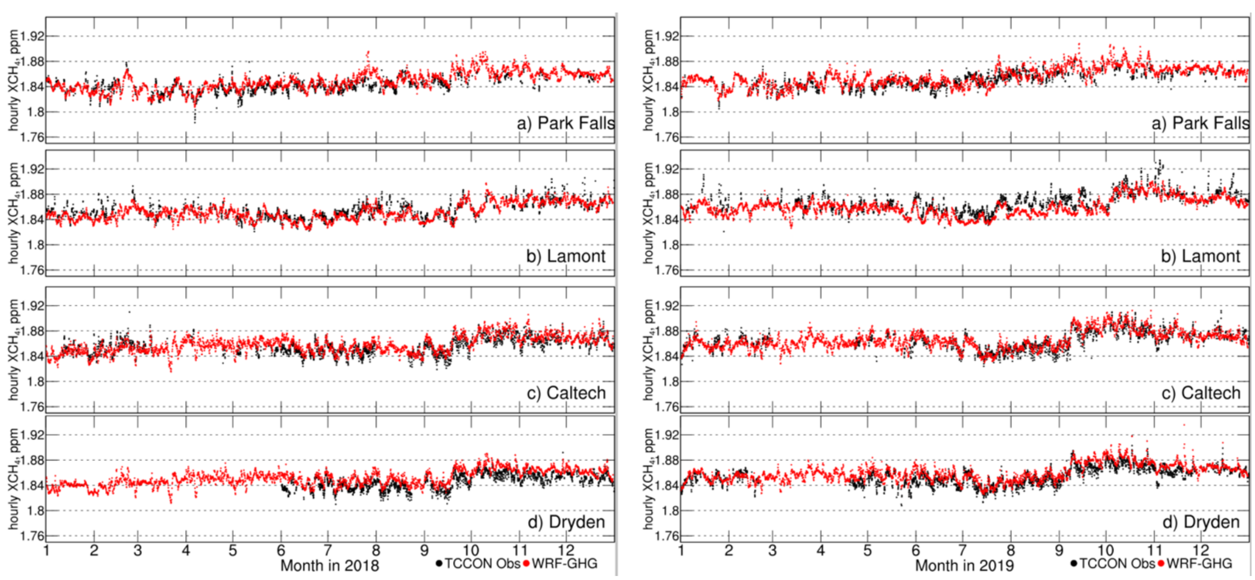
Abstract

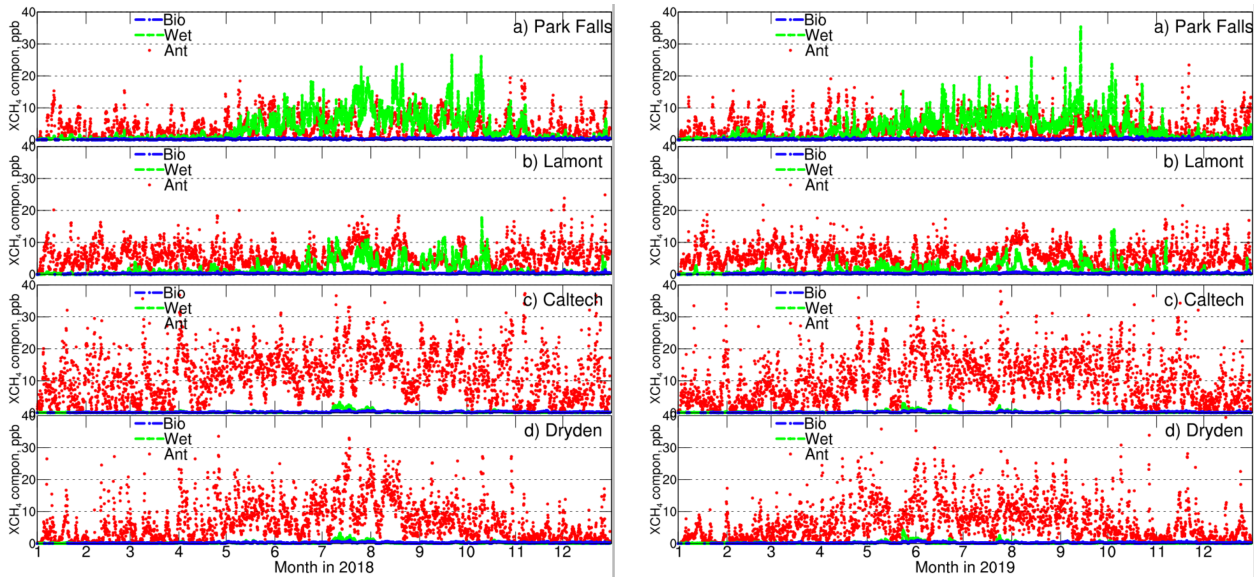
Sources and sinks of the two most important greenhouse gases CO_2 and CH_4 at regional to continental scales remain poorly understood. In our previous work, the WRF-VPRM, a weather-biosphere-online-coupled model in which the biogenic CO_2 fluxes are handled by the Vegetation Photosynthesis and Respiration Model (VPRM), was further developed by coupling with the CarbonTracker global CO_2 simulation and incorporating optimized terrestrial CO_2 flux parameterization (Hu et al., 2021; Hu et al., 2020). In this work, an enhanced version of WRF-VPRM by including CH_4 (referred to as WRF-GHG hereafter) is further developed by coupling with the Copernicus Atmosphere Monitoring Service (CAMS) CH_4 global simulation for the initial and boundary conditions and the *WetCHARTs* wetland CH_4 emissions and NEI2017 anthropogenic CH_4 emissions, which dominate emissions over the contiguous United States (CONUS). Yearly WRF-GHG simulations are conducted for year 2018 and 2019 over CONUS at a horizontal grid spacing of 12 km to examine the impact of 2019 abnormal mid-west precipitation on CO_2 and CH_4 fluxes and atmospheric concentrations, with the simulation for 2018 serving as a baseline for comparison, similarly to Yin et al (2020). Simulated CO_2 and CH_4 are evaluated using remotely sensed data from Total Carbon Column Observing Network (TCCON), OCO-2, TROPOMI, and in-situ measurements from the GLOBALVIEW obspack data. WRF-GHG has been shown to capture the monthly variation of column-averaged CO_2 concentrations (XCO_2) and episodic variations associated with frontal passages. In this work, we will show that TCCON XCH_4 shows mild seasonal variation and more prominent episodic variations, which are captured by WRF-GHG. As a case study, the 2019 May flood delayed growing season in mid-west and the typical spring and summer drawdown of atmospheric CO_2 by 1-3 weeks. Obspack and TROPOMI data indicate higher CH_4 in the mid-west in July and August, in 2019 relative to 2018, which we hypothesize is related to the abnormal precipitation in 2019 in the region that induces more wetland CH_4 emissions. The WRF-GHG model significantly underestimates CH_4 concentration in mid-west in summer 2019 when the *WetCHARTs* wetland CH_4 emissions are driven by ERA-Interim reanalysis precipitation, which is known to be underestimated. An updated *WetCHARTs* wetland CH_4 emissions driven by the PRISM precipitation data are currently being produced at JPL, which are expected to reduce the WRF-GHG CH_4 bias, as wetland fluxes are highly sensitive to inundation from precipitation.

There are a few innovation points in this story: 1. impact of 2019 flood on CO_2 is for the first time examined using a weather-biosphere-online-coupled model, 2. WRF-GHG is applied to continental scale to examine year-long CH_4 that is affected dominantly by both wetland and anthropogenic CH_4 emissions for the 1st time.

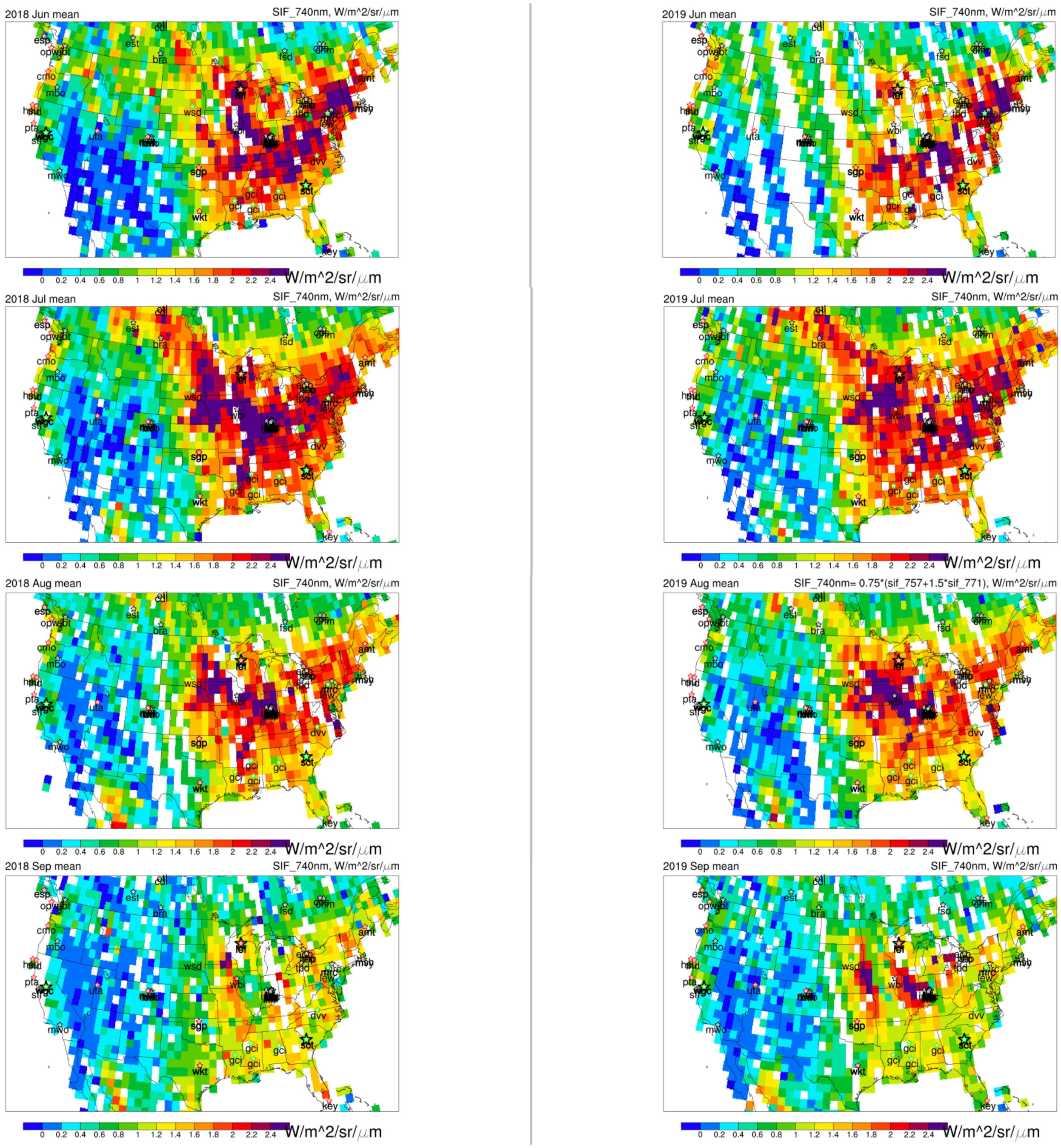
A nested-domain WRF-GHG simulation is conducted with the 2nd domain with a grid spacing of 800 m covering Southwest Oklahoma to examine CH_4 plumes from point sources. Impact of diurnal variation of the atmospheric boundary layer on CH_4 plumes is demonstrated.

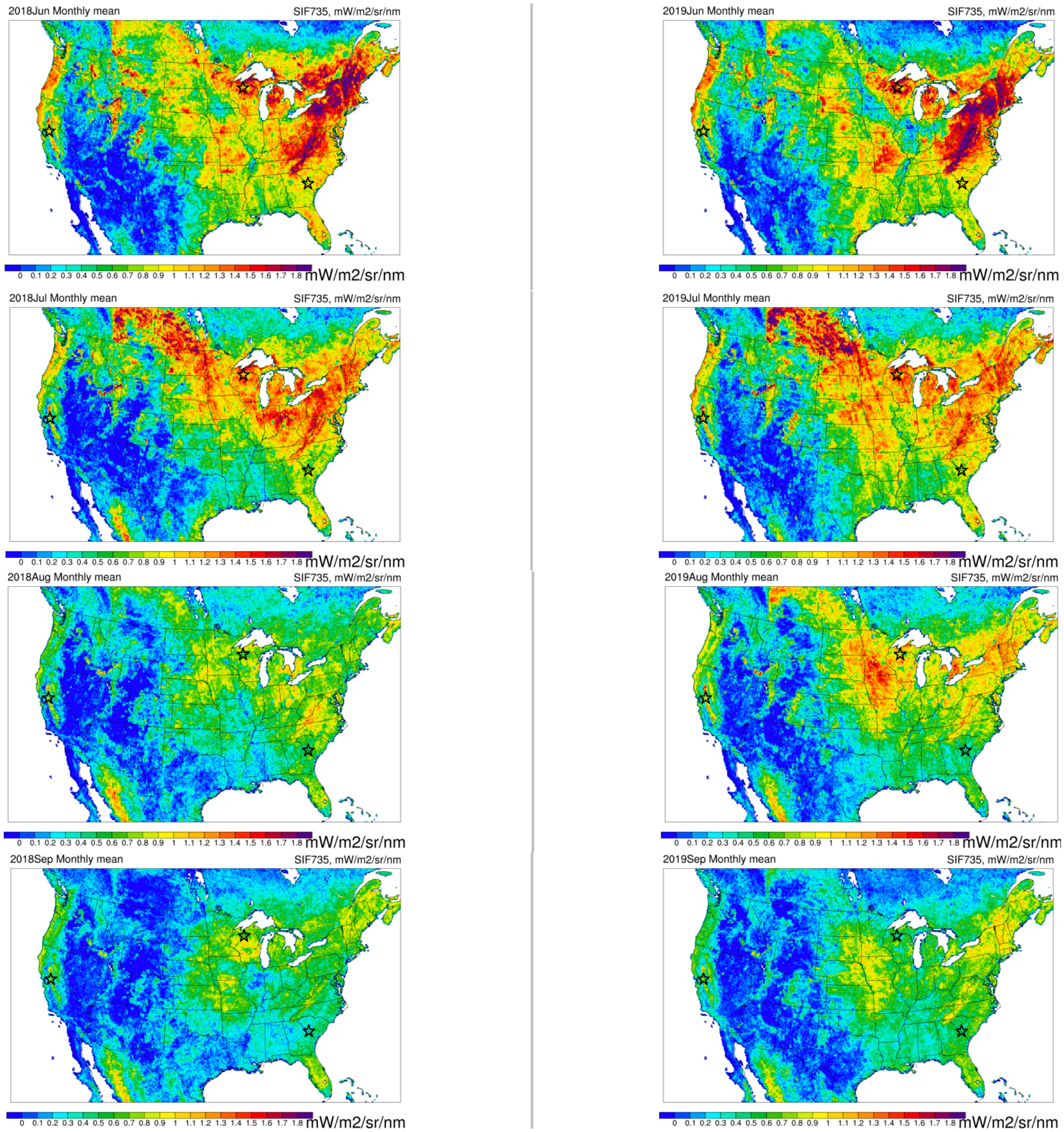




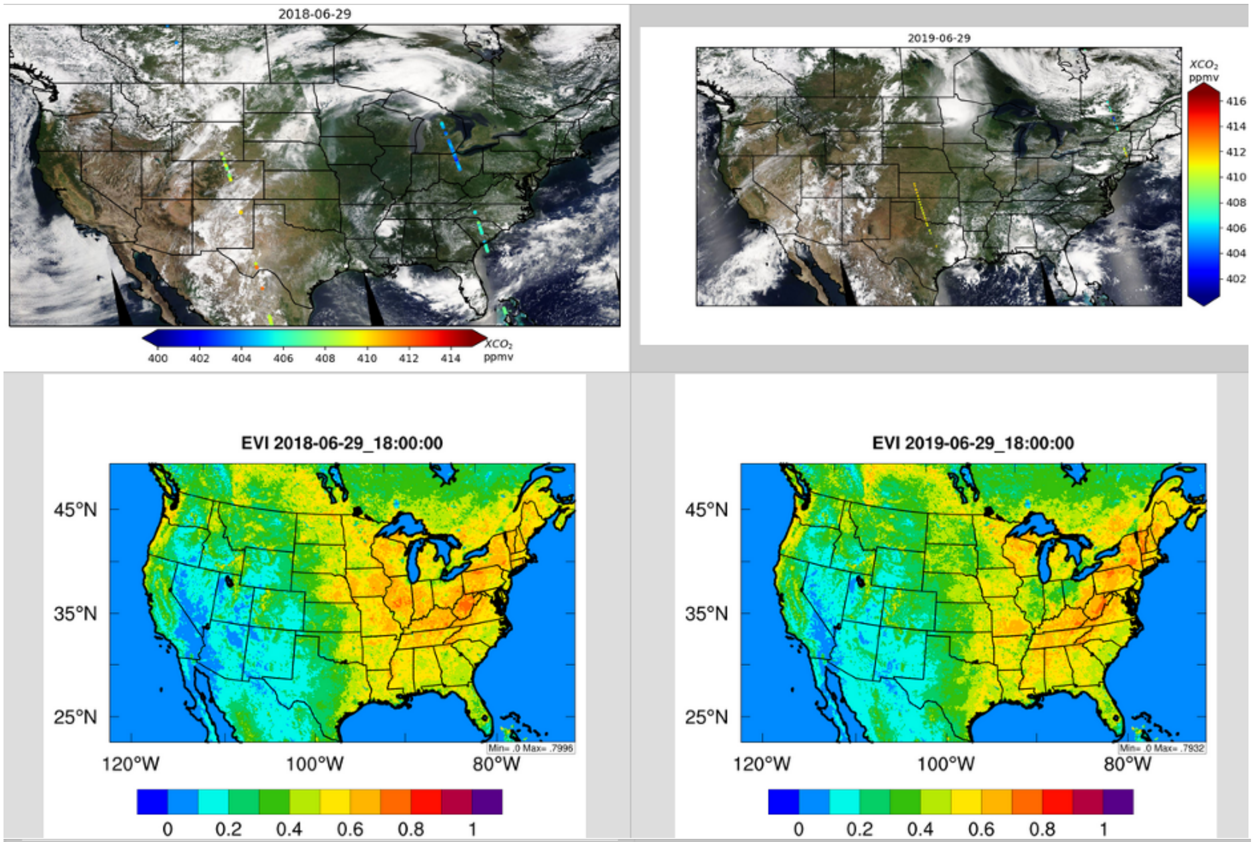


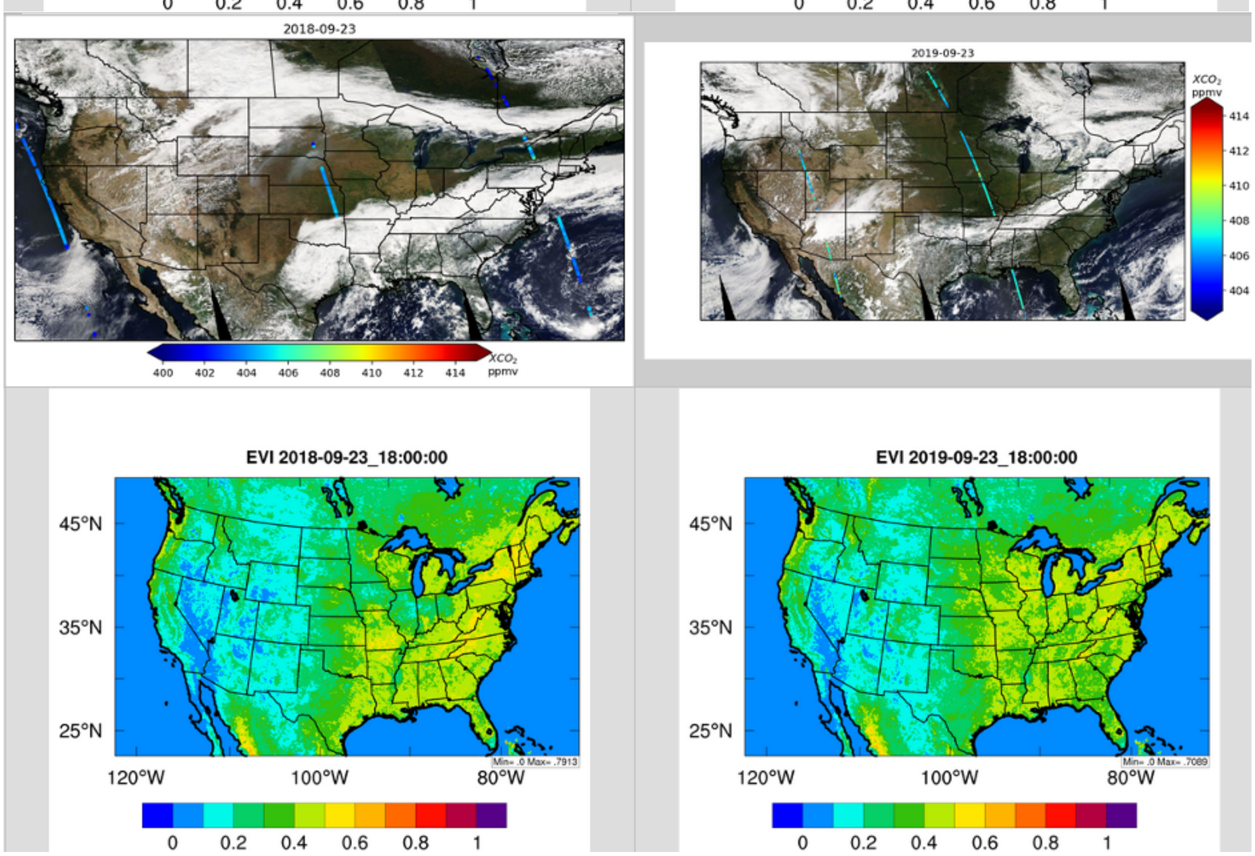
Bio
Wet
Ant
a) Park Falls
b) Lamont
c) Caltech
d) Dryden
XCH$_4$ compon, ppb
Month in 2018
Month in 2019


2018 Jun mean
SIF_740nm, W/m^2/sr/μm
2019 Jun mean
SIF_740nm, W/m^2/sr/μm
2018 Jul mean
SIF_740nm, W/m^2/sr/μm
2019 Jul mean
SIF_740nm, W/m^2/sr/μm
2018 Aug mean
SIF_740nm, W/m^2/sr/μm
2019 Aug mean
SIF_740nm= 0.75*(sif_757+1.5*sif_771), W/m^2/sr/μm
2018 Sep mean
SIF_740nm, W/m^2/sr/μm
2019 Sep mean
SIF_740nm, W/m^2/sr/μm
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4
W/m^2/sr/μm

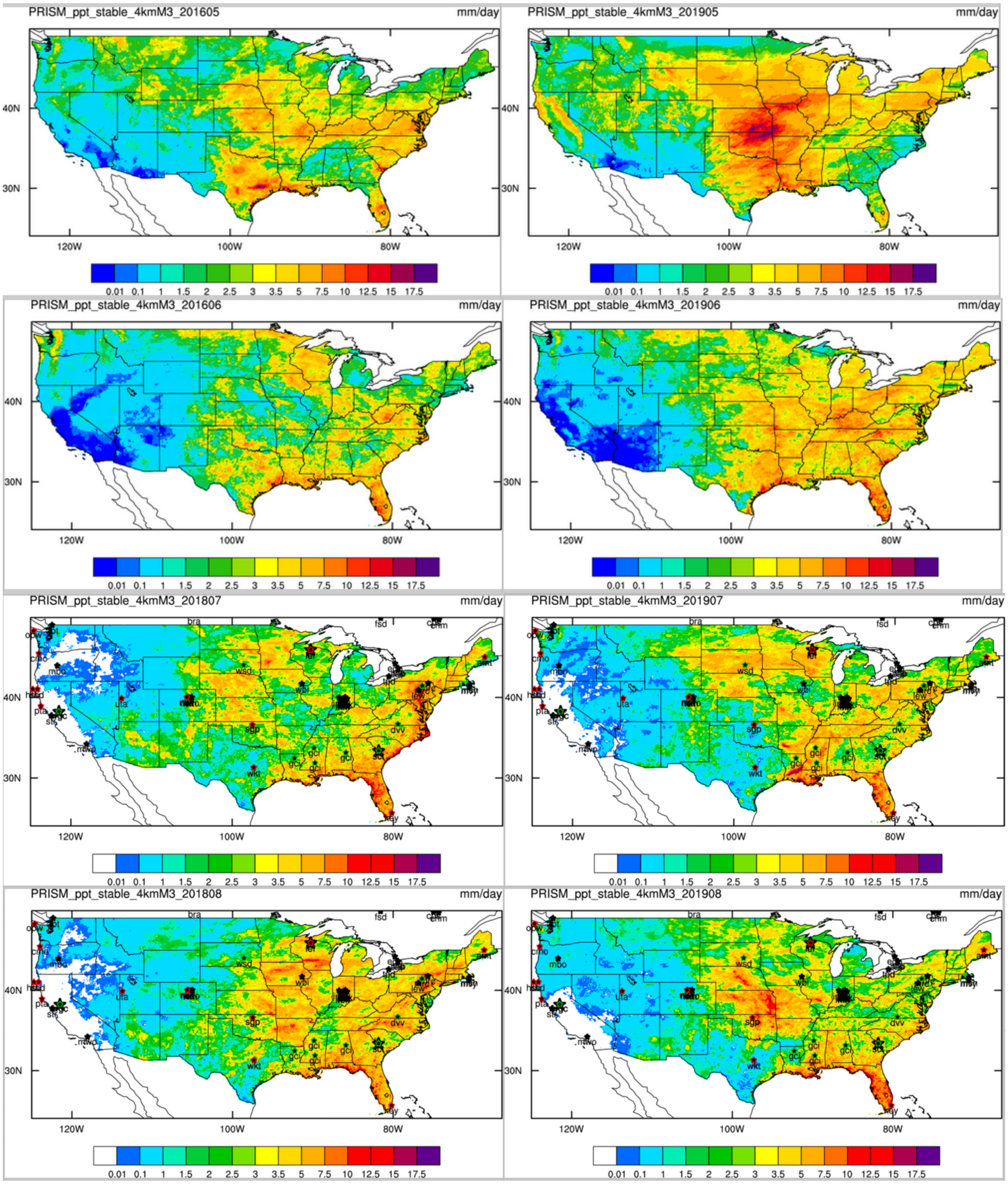


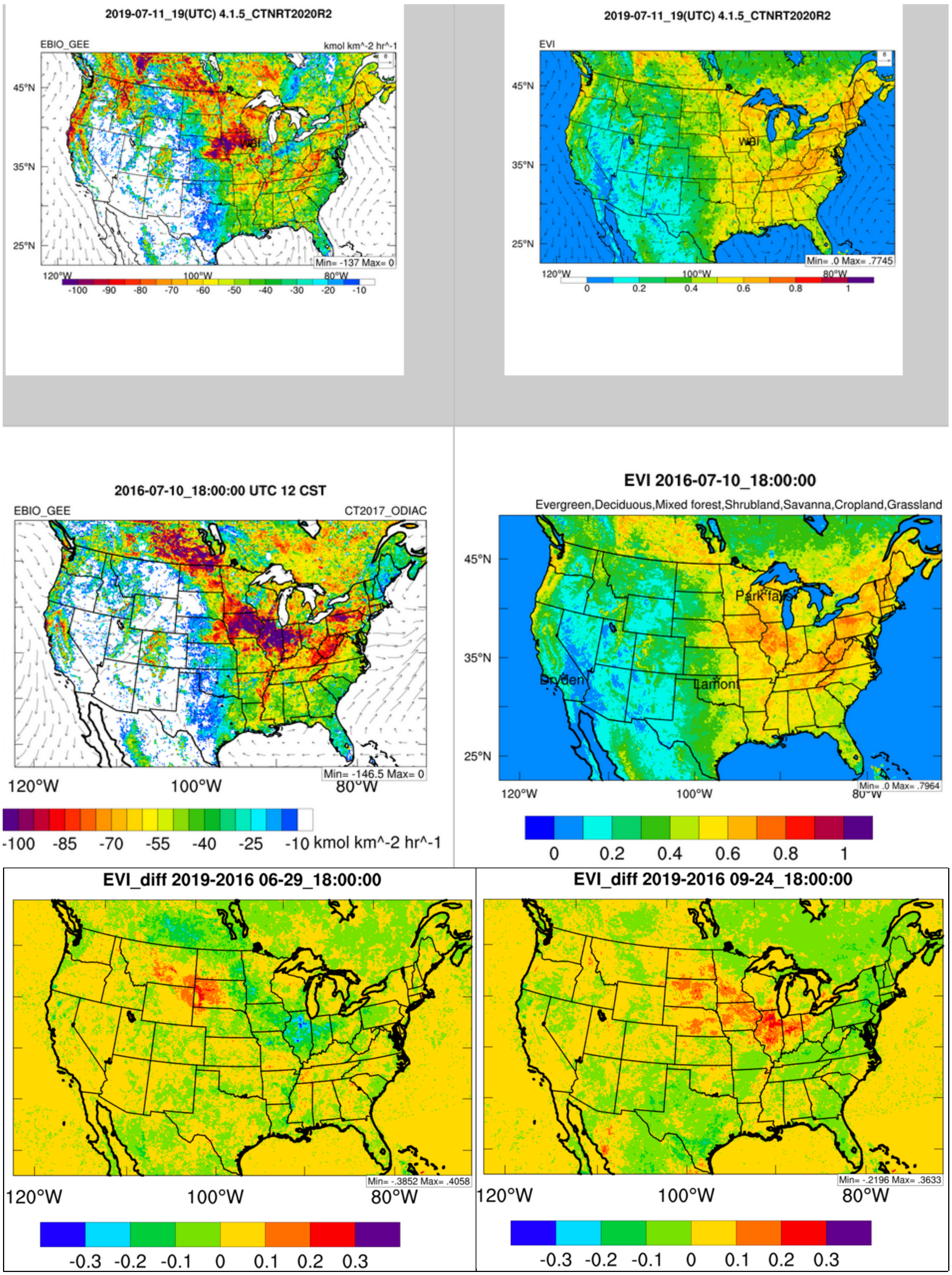
2018Jun Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm
2019Jun Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm
2018Jul Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm
2019Jul Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm
2018Aug Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm
2019Aug Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm
2018Sep Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm
2019Sep Monthly mean
SIF735, mW/m2/sr/nm
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mW/m2/sr/nm

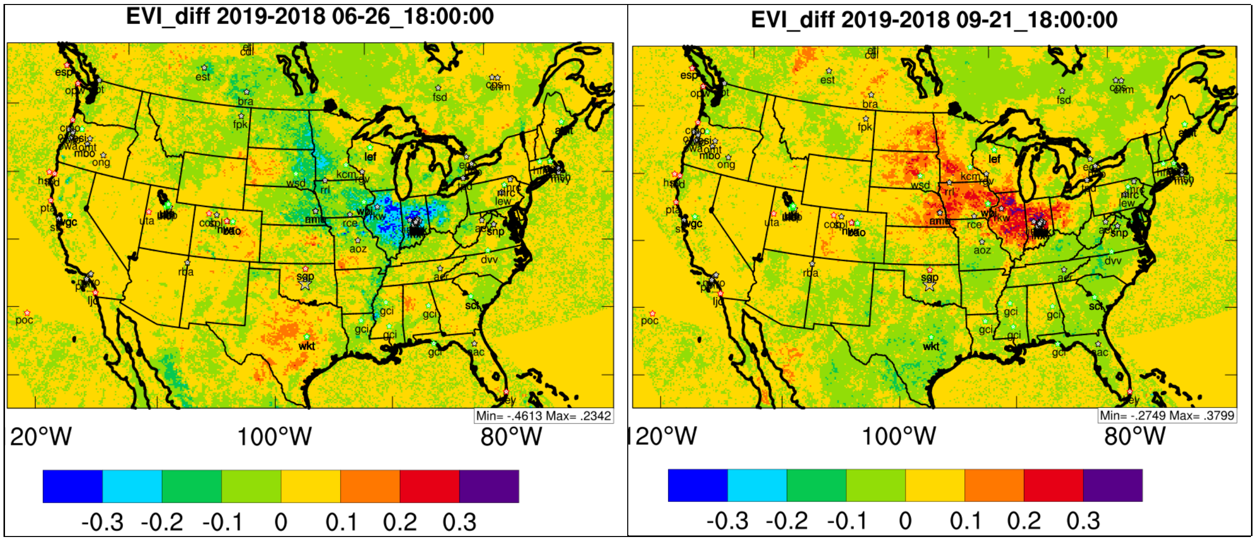


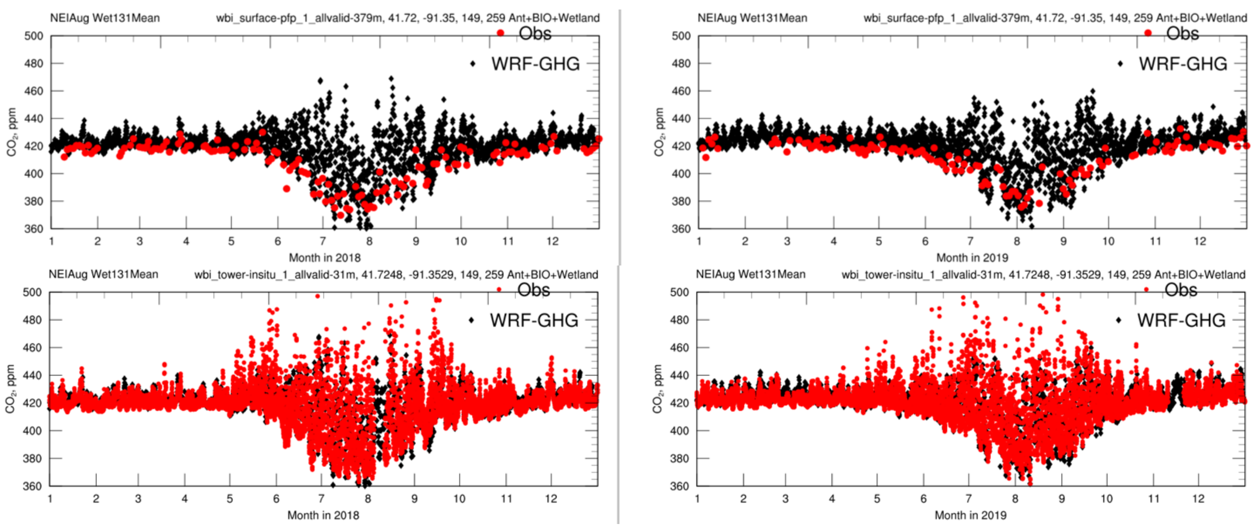


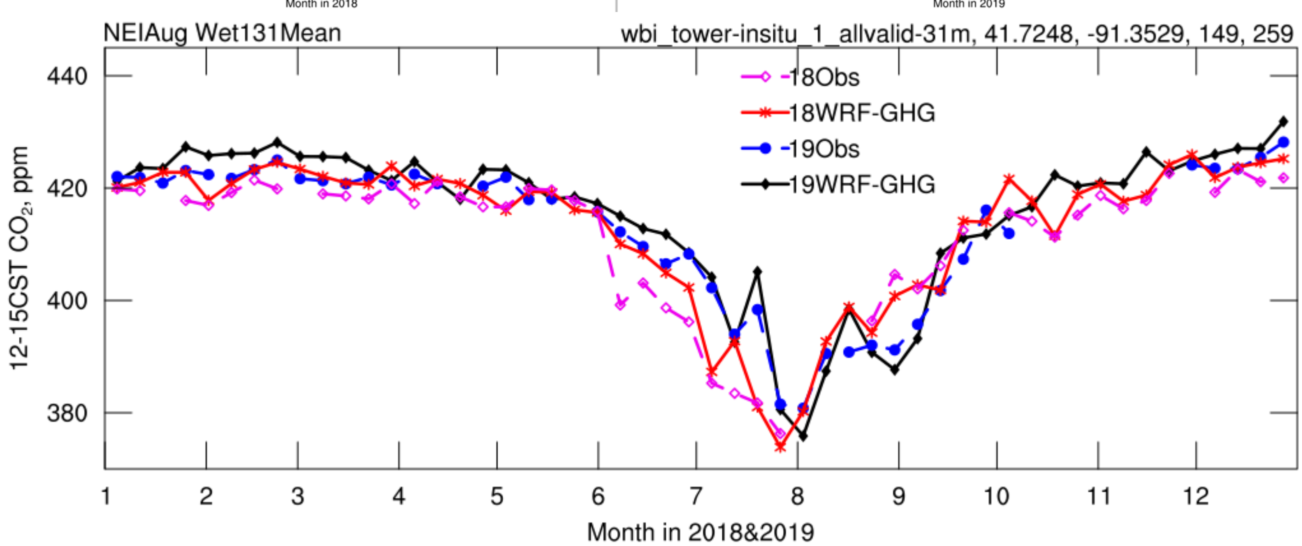
Comparison of precipitation between 2018 and 2019

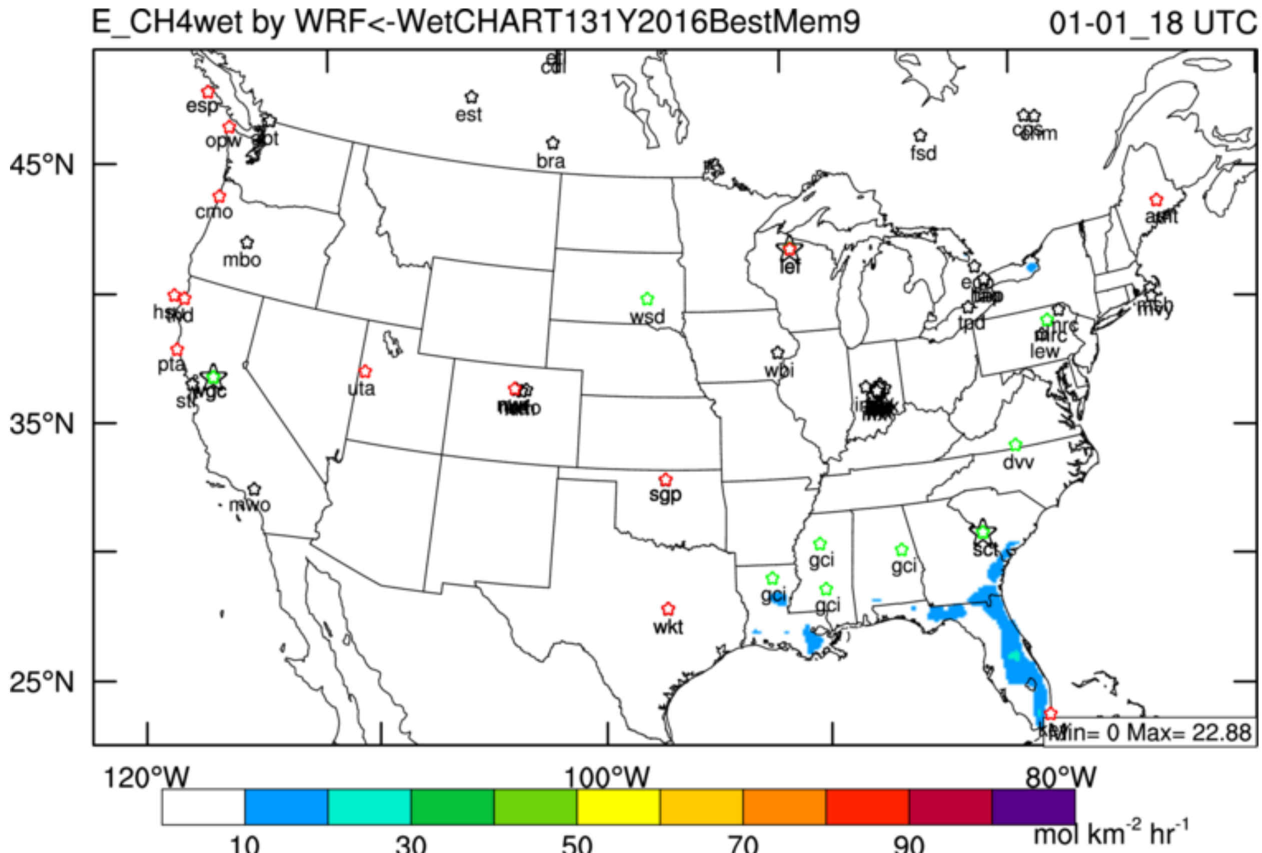

PRISM_ppt_stable_4kmM3_201605
mm/day
PRISM_ppt_stable_4kmM3_201905
mm/day
PRISM_ppt_stable_4kmM3_201606
mm/day
PRISM_ppt_stable_4kmM3_201906
mm/day
PRISM_ppt_stable_4kmM3_201807
mm/day
PRISM_ppt_stable_4kmM3_201907
mm/day
PRISM_ppt_stable_4kmM3_201808
mm/day
PRISM_ppt_stable_4kmM3_201908
mm/day
40N
30N
120W
100W
80W
0.01 0.1 1 1.5 2 2.5 3 3.5 5 7.5 10 12.5 15 17.5

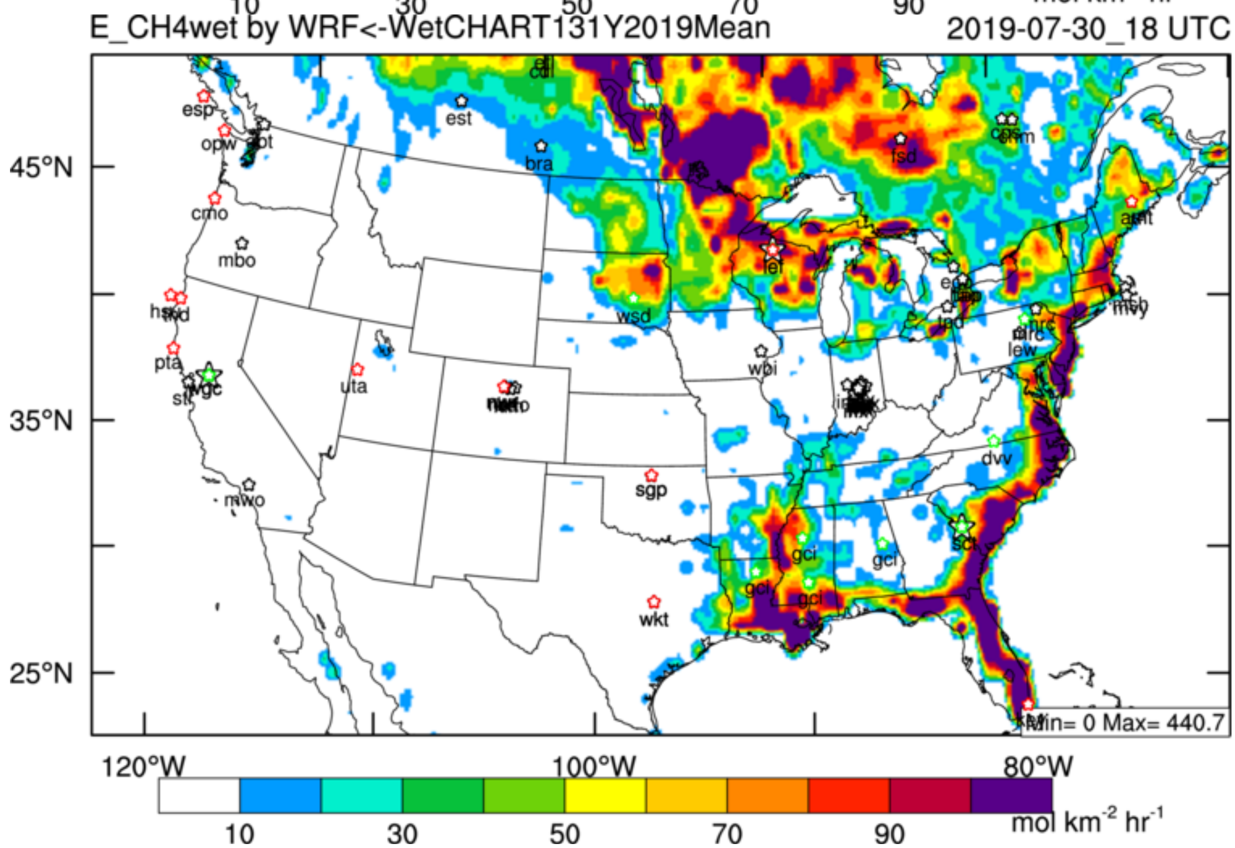

2019-07-11_19(UTC) 4.1.5_CTNRT2020R2
EBIO_GEE
kmol km^-2 hr^-1
Wal
Min= -137 Max= 0
45°N
35°N
25°N
120°W
100°W
80°W
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10
2019-07-11_19(UTC) 4.1.5_CTNRT2020R2
EVI
Wal
Min= .0 Max= .7745
0 0.2 0.4 0.6 0.8 1
2016-07-10_18:00:00 UTC 12 CST
EBIO_GEE
CT2017_ODIAC
Min= -146.5 Max= 0
-100 -85 -70 -55 -40 -25 -10 kmol km^-2 hr^-1
EVI 2016-07-10_18:00:00
Evergreen,Deciduous,Mixed forest,Shrubland,Savanna,Cropland,Grassland
Park falls
Dryden
Lamont
Min= .0 Max= .7964
0 0.2 0.4 0.6 0.8 1
EVI_diff 2019-2016 06-29_18:00:00
Min= -.3852 Max= .4058
-0.3 -0.2 -0.1 0 0.1 0.2 0.3
EVI_diff 2019-2016 09-24_18:00:00
Min= -.2196 Max= .3633
-0.3 -0.2 -0.1 0 0.1 0.2 0.3


EVI_diff 2019-2018 06-26_18:00:00
Min= -.4613 Max= .2342
20°W
100°W
80°W
-0.3 -0.2 -0.1 0 0.1 0.2 0.3
EVI_diff 2019-2018 09-21_18:00:00
Min= -.2749 Max= .3799
120°W
100°W
80°W
-0.3 -0.2 -0.1 0 0.1 0.2 0.3

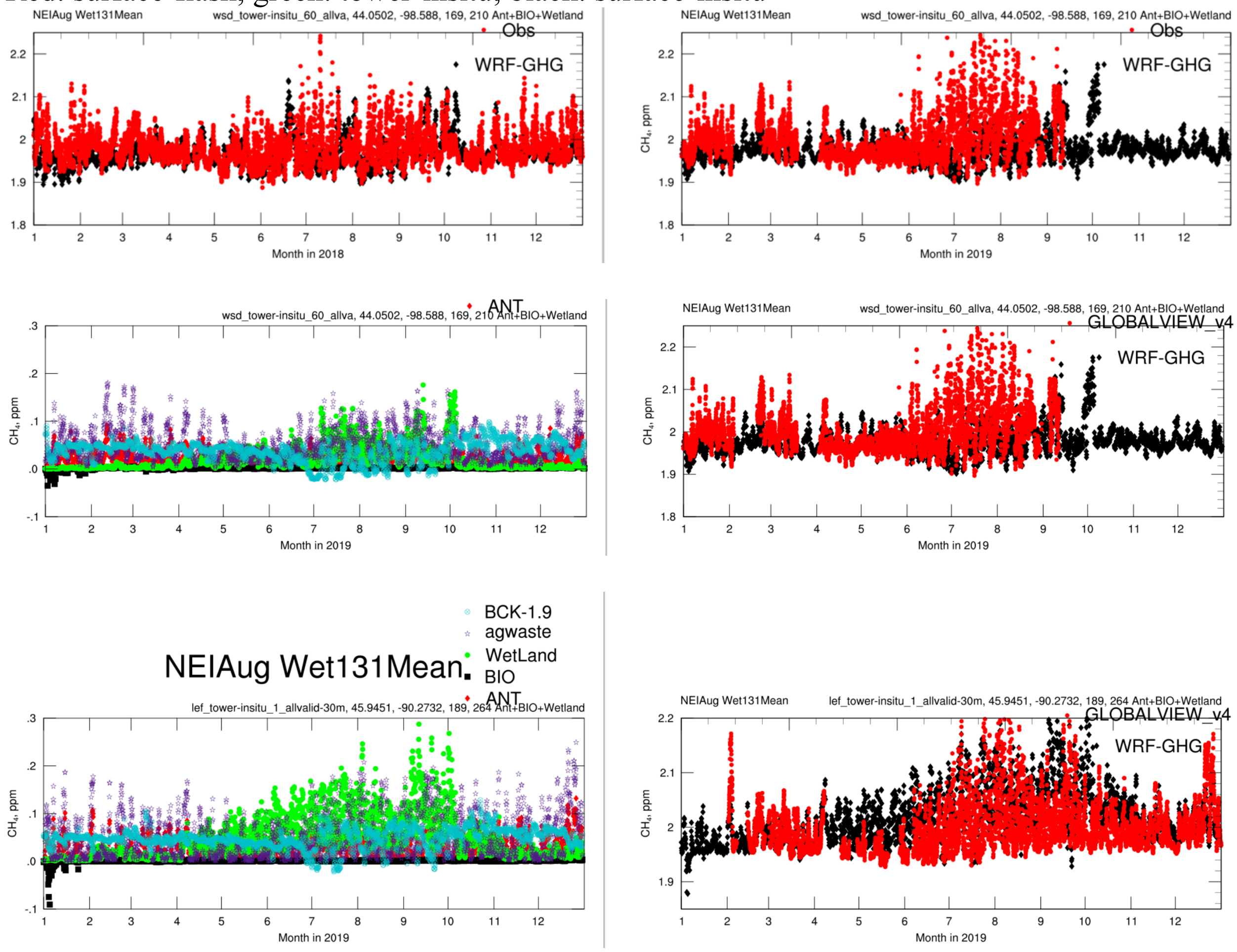

NEIAug Wet131Mean
wbi_surface-pfp_1_allvalid-379m, 41.72, -91.35, 149, 259 Ant+BIO+Wetland
Obs
WRF-GHG
CO2, ppm
Month in 2018
Month in 2019
wbi_tower-insitu_1_allvalid-31m, 41.7248, -91.3529, 149, 259 Ant+BIO+Wetland

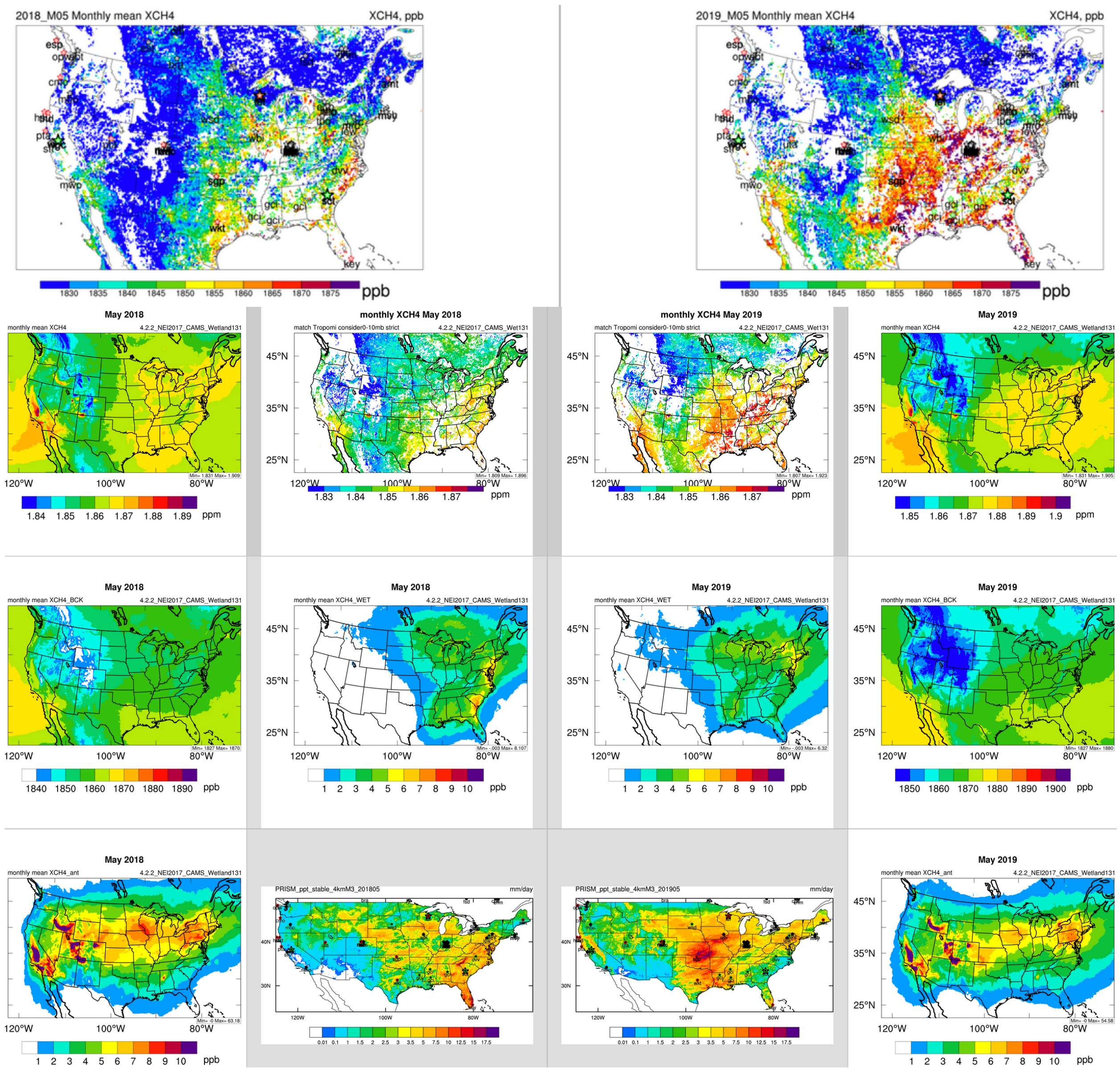

NEIAug Wet131Mean
wbi_tower-insitu_1_allvalid-31m, 41.7248, -91.3529, 149, 259
18Obs
18WRF-GHG
19Obs
19WRF-GHG
12-15CST CO2, ppm
Month in 2018&2019


E_CH4wet by WRF<-WetCHART131Y2016BestMem9
01-01_18 UTC
45°N
35°N
25°N
120°W
100°W
80°W
Min= 0 Max= 22.88
10
30
50
70
90
mol km^{-2} hr^{-1}

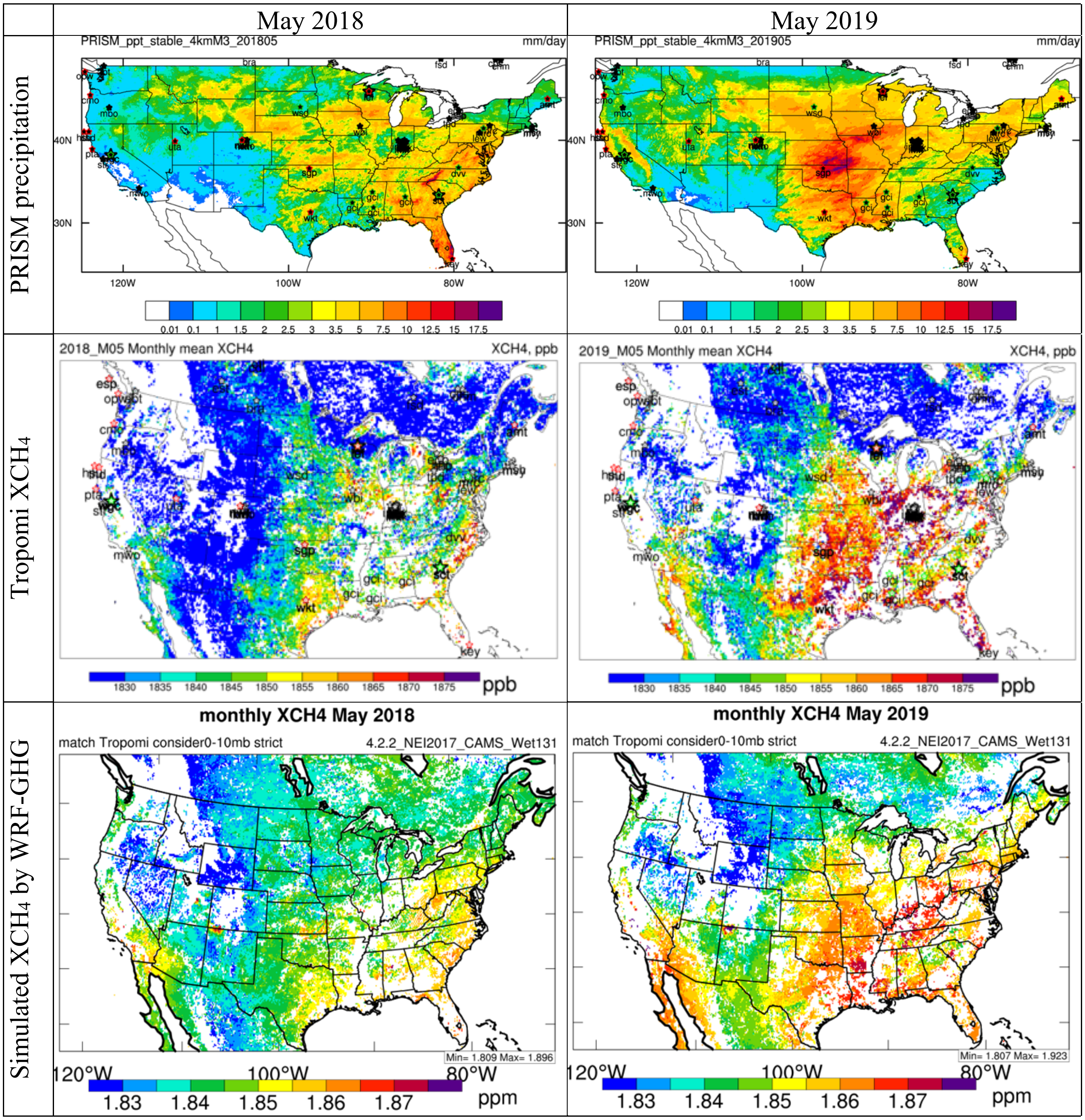

E_CH4wet by WRF<-WetCHART131Y2019Mean
2019-07-30_18 UTC
45°N
35°N
25°N
120°W
100°W
80°W
Min= 0 Max= 440.7
10
30
50
70
90
mol km^{-2} hr^{-1}

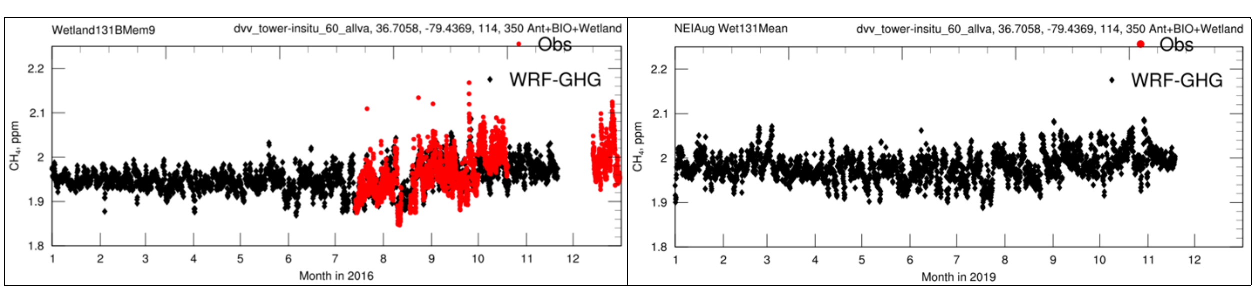
Red: surface-flask; green: tower-insitu; black: surface-insitu

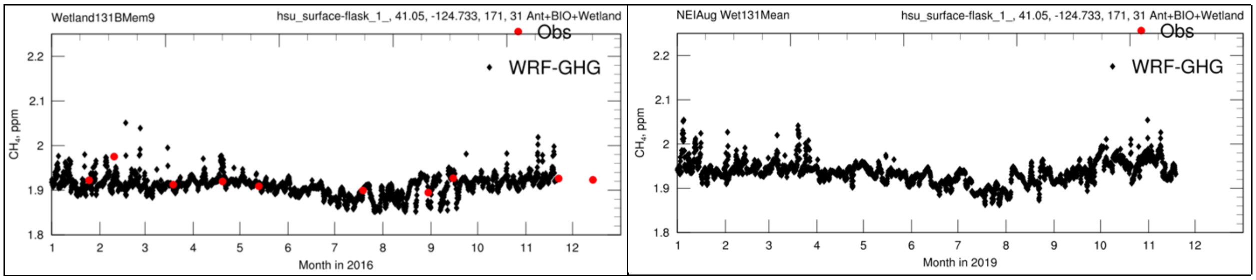


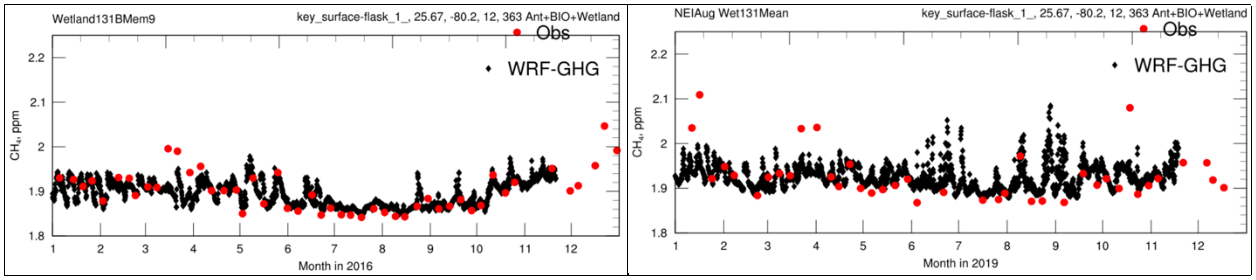


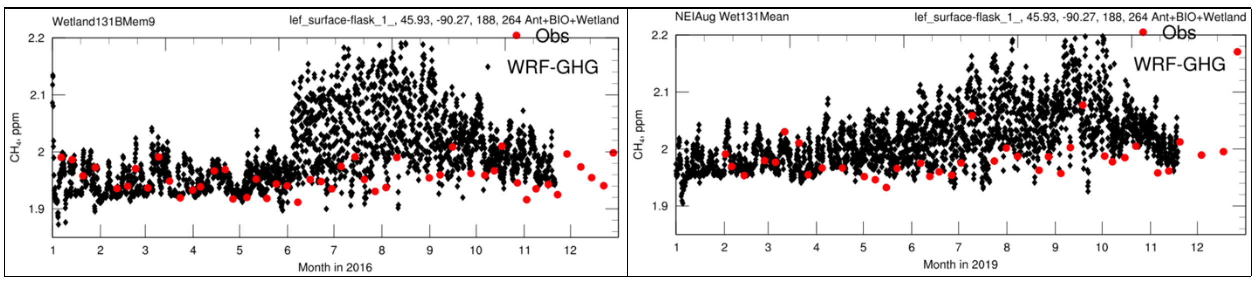
2018_M05 Monthly mean XCH4
XCH4, ppb
2019_M05 Monthly mean XCH4
XCH4, ppb
1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 ppb
May 2018
monthly mean XCH4
4.2.2_NEI2017_CAMS_Wetland131
1.84 1.85 1.86 1.87 1.88 1.89 ppm
monthly XCH4 May 2018
match Tropomi consider0-10mb strict
4.2.2_NEI2017_CAMS_Wet131
1.83 1.84 1.85 1.86 1.87 ppm
monthly XCH4 May 2019
match Tropomi consider0-10mb strict
4.2.2_NEI2017_CAMS_Wet131
1.83 1.84 1.85 1.86 1.87 ppm
May 2019
monthly mean XCH4
4.2.2_NEI2017_CAMS_Wetland131
1.85 1.86 1.87 1.88 1.89 1.9 ppm
May 2018
monthly mean XCH4_BCK
4.2.2_NEI2017_CAMS_Wetland131
1840 1850 1860 1870 1880 1890 ppb
May 2018
monthly mean XCH4_WET
4.2.2_NEI2017_CAMS_Wetland131
1 2 3 4 5 6 7 8 9 10 ppb
May 2019
monthly mean XCH4_WET
4.2.2_NEI2017_CAMS_Wetland131
1 2 3 4 5 6 7 8 9 10 ppb
May 2019
monthly mean XCH4_BCK
4.2.2_NEI2017_CAMS_Wetland131
1850 1860 1870 1880 1890 1900 ppb
May 2018
monthly mean XCH4_ant
4.2.2_NEI2017_CAMS_Wetland131
1 2 3 4 5 6 7 8 9 10 ppb
PRISM_ppt_stable_4kmM3_201805
mm/day
PRISM_ppt_stable_4kmM3_201905
mm/day
0.01 0.1 1 1.5 2 2.5 3 3.5 5 7.5 10 12.5 15 17.5
May 2019
monthly mean XCH4_ant
4.2.2_NEI2017_CAMS_Wetland131
1 2 3 4 5 6 7 8 9 10 ppb
120°W
100°W
80°W
45°N
35°N
25°N

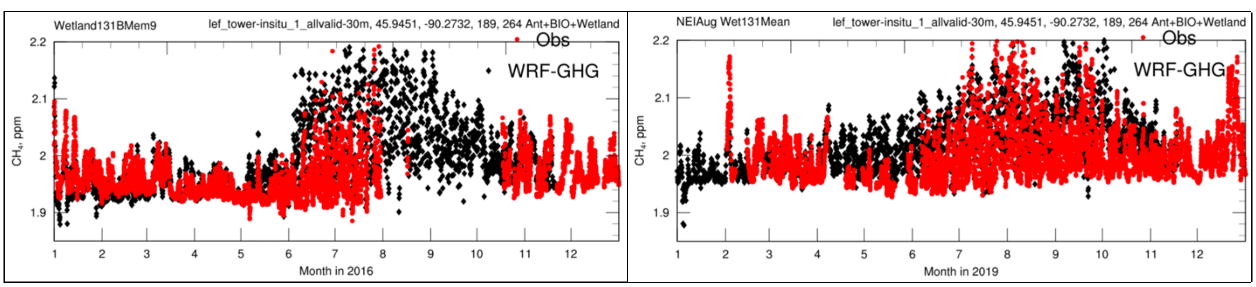

May 2018
May 2019
PRISM precipitation
PRISM_ppt_stable_4kmM3_201805
PRISM_ppt_stable_4kmM3_201905
mm/day
40N
30N
120W
100W
80W
0.01 0.1 1 1.5 2 2.5 3 3.5 5 7.5 10 12.5 15 17.5
Tropomi XCH4
2018_M05 Monthly mean XCH4
2019_M05 Monthly mean XCH4
XCH4, ppb
1830 1835 1840 1845 1850 1855 1860 1865 1870 1875
ppb
Simulated XCH4 by WRF-GHG
monthly XCH4 May 2018
monthly XCH4 May 2019
match Tropomi consider0-10mb strict
4.2.2_NEI2017_CAMS_Wet131
Min= 1.809 Max= 1.896
Min= 1.807 Max= 1.923
120°W
100°W
80°W
1.83 1.84 1.85 1.86 1.87
ppm

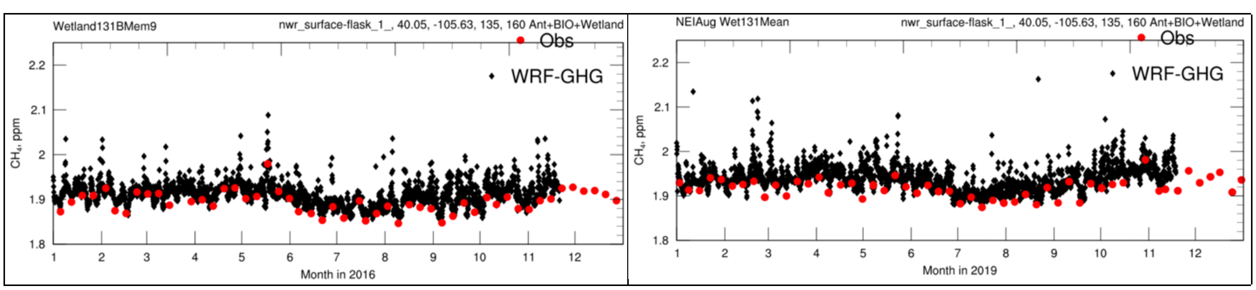

Wetland131BMem9
dvv_tower-insitu_60_allva, 36.7058, -79.4369, 114, 350 Ant+BIO+Wetland
NEIAug Wet131Mean
Obs
WRF-GHG
CH4, ppm
Month in 2016
Month in 2019

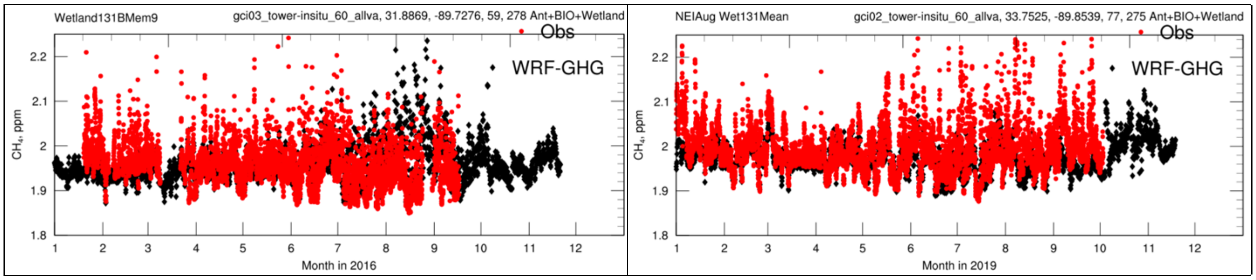

Wetland131BMem9
hsu_surface-flask_1_, 41.05, -124.733, 171, 31 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
hsu_surface-flask_1_, 41.05, -124.733, 171, 31 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

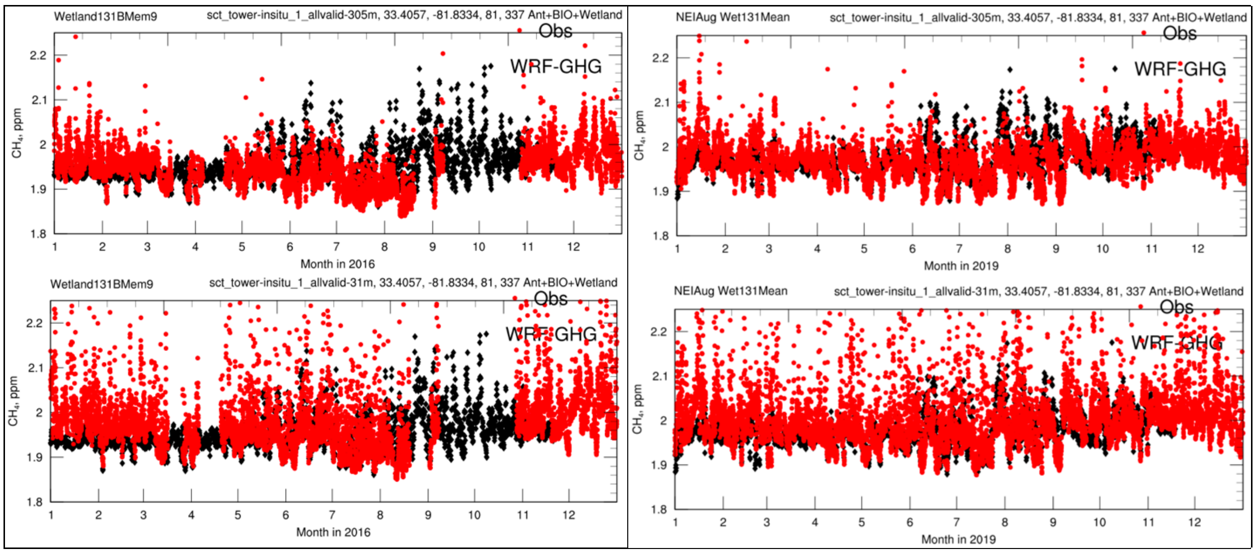

Wetland131BMem9
key_surface-flask_1_, 25.67, -80.2, 12, 363 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
key_surface-flask_1_, 25.67, -80.2, 12, 363 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

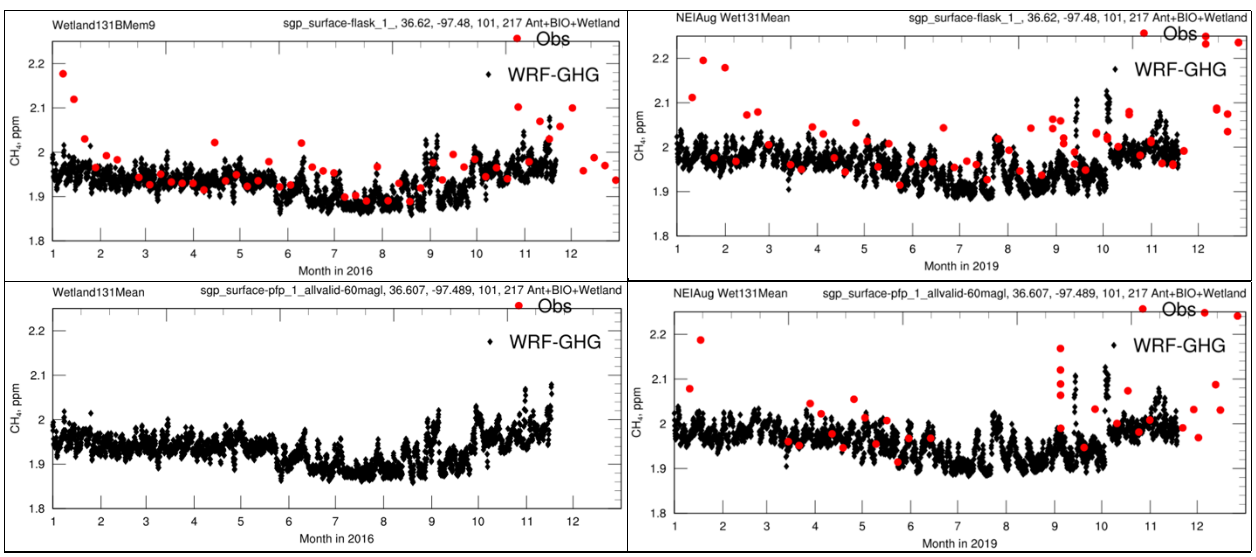

Wetland131BMem9
lef_surface-flask_1_, 45.93, -90.27, 188, 264 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
lef_surface-flask_1_, 45.93, -90.27, 188, 264 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

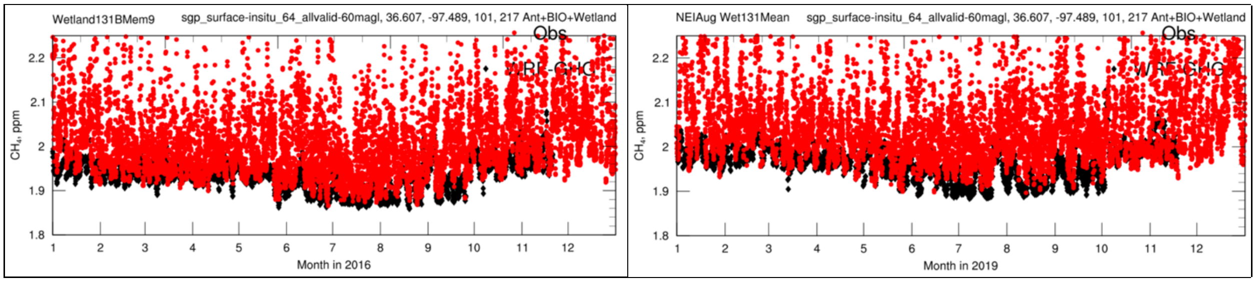

Wetland131BMem9
lef_tower-insitu_1_allvalid-30m, 45.9451, -90.2732, 189, 264 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
lef_tower-insitu_1_allvalid-30m, 45.9451, -90.2732, 189, 264 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

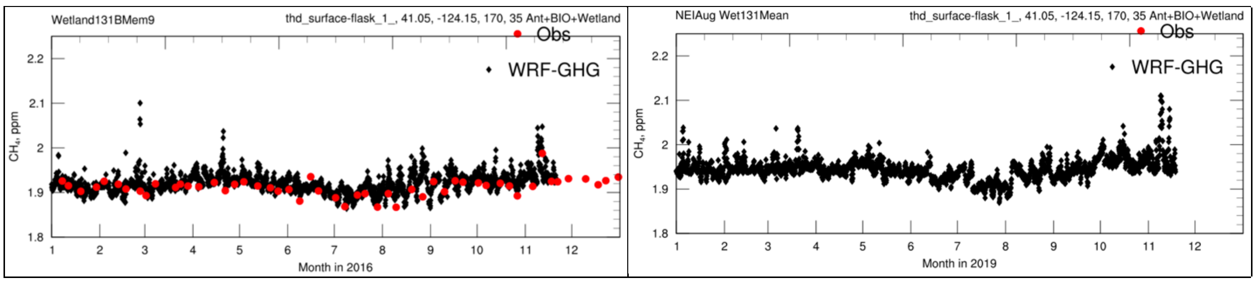

Wetland131BMem9
nwr_surface-flask_1_, 40.05, -105.63, 135, 160 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
nwr_surface-flask_1_, 40.05, -105.63, 135, 160 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

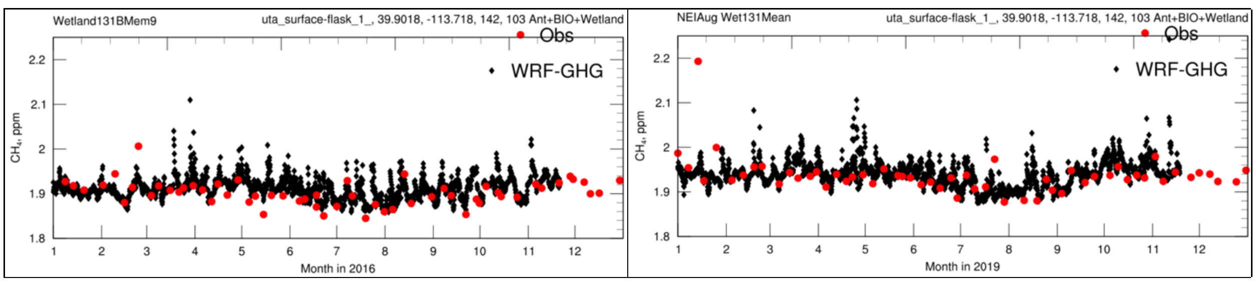

Wetland131BMem9
gci03_tower-insitu_60_allva, 31.8869, -89.7276, 59, 278 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
gci02_tower-insitu_60_allva, 33.7525, -89.8539, 77, 275 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

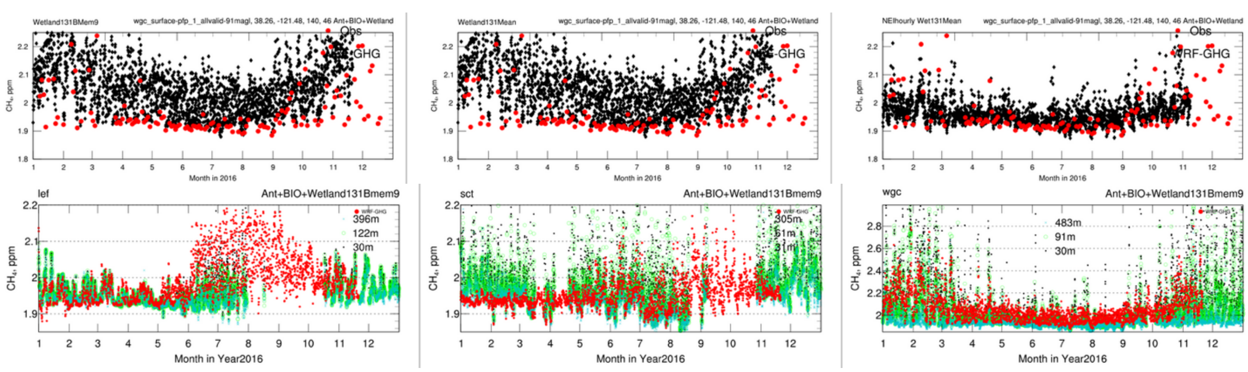

Wetland131BMem9
sct_tower-insitu_1_allvalid-305m, 33.4057, -81.8334, 81, 337 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
sct_tower-insitu_1_allvalid-305m, 33.4057, -81.8334, 81, 337 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019
Wetland131BMem9
sct_tower-insitu_1_allvalid-31m, 33.4057, -81.8334, 81, 337 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
sct_tower-insitu_1_allvalid-31m, 33.4057, -81.8334, 81, 337 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

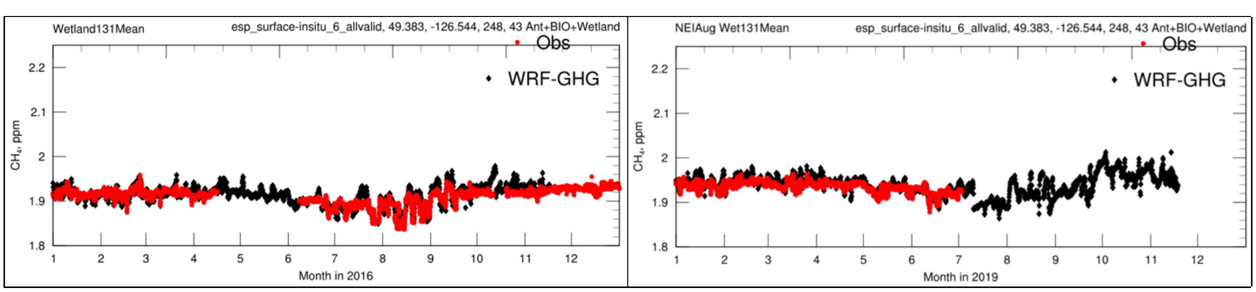

Wetland131BMem9
sgp_surface-flask_1_, 36.62, -97.48, 101, 217 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
sgp_surface-flask_1_, 36.62, -97.48, 101, 217 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019
Wetland131Mean
sgp_surface-pfp_1_allvalid-60magl, 36.607, -97.489, 101, 217 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
sgp_surface-pfp_1_allvalid-60magl, 36.607, -97.489, 101, 217 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

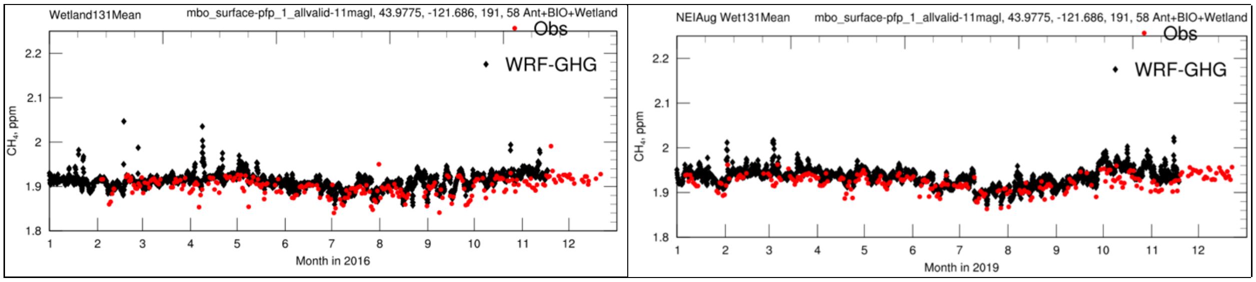

Wetland131BMem9
sgp_surface-insitu_64_allvalid-60magl, 36.607, -97.489, 101, 217 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
sgp_surface-insitu_64_allvalid-60magl, 36.607, -97.489, 101, 217 Ant+BIO+Wetland
Month in 2019

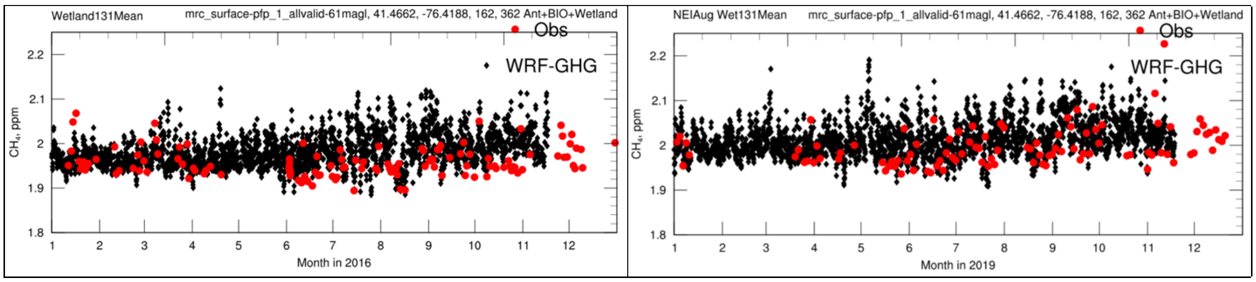

Wetland131BMem9
thd_surface-flask_1_, 41.05, -124.15, 170, 35 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
thd_surface-flask_1_, 41.05, -124.15, 170, 35 Ant+BIO+Wetland
Month in 2019

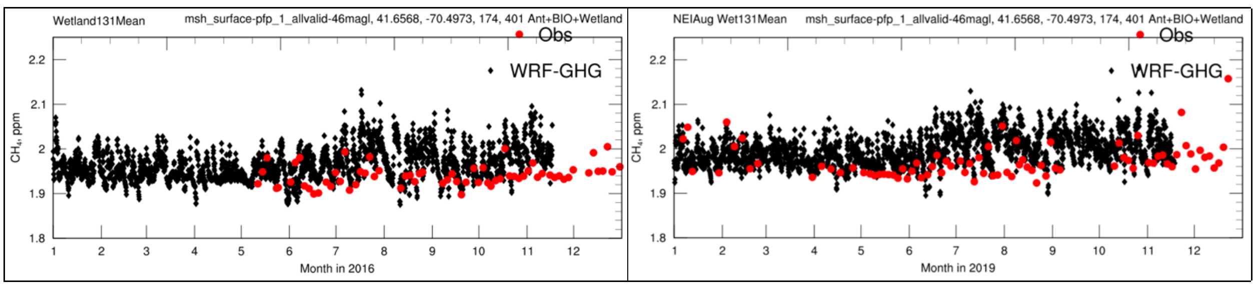

Wetland131BMem9
uta_surface-flask_1_, 39.9018, -113.718, 142, 103 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
uta_surface-flask_1_, 39.9018, -113.718, 142, 103 Ant+BIO+Wetland
Month in 2019

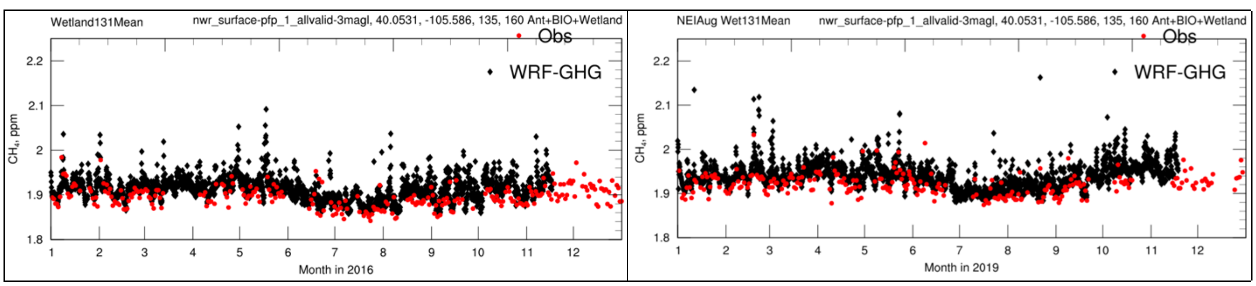

Wetland131BMem9
Wetland131Mean
NEIhourly Wet131Mean
wgc_surface-pfp_1_allvalid-91magl, 38.26, -121.48, 140, 46 Ant+BIO+Wetland
Obs
WRF-GHG
Month in 2016
lef
sct
wgc
Ant+BIO+Wetland131Bmem9
396m
122m
30m
305m
91m
31m
483m
91m
30m
Month in Year2016

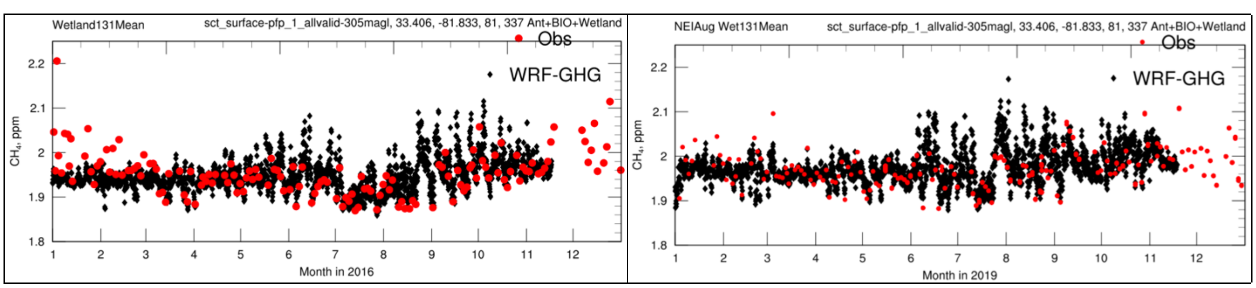

Wetland131Mean
esp_surface-insitu_6_allvalid, 49.383, -126.544, 248, 43 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
esp_surface-insitu_6_allvalid, 49.383, -126.544, 248, 43 Ant+BIO+Wetland
Month in 2019

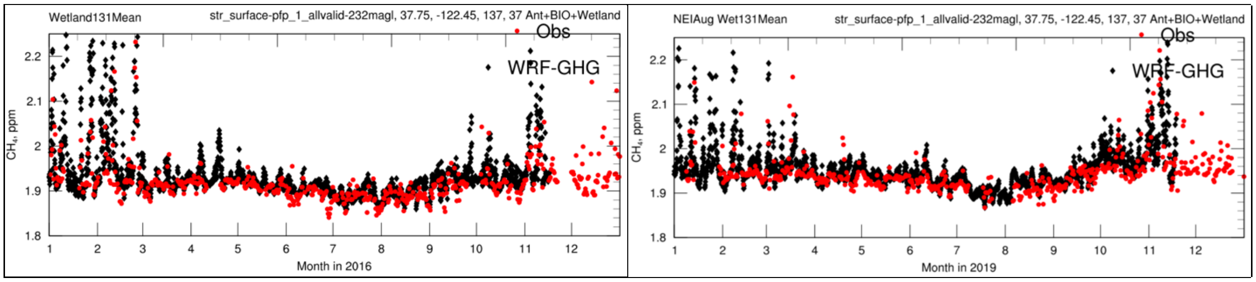

Wetland131Mean
mbo_surface-pfp_1_allvalid-11magl, 43.9775, -121.686, 191, 58 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
mbo_surface-pfp_1_allvalid-11magl, 43.9775, -121.686, 191, 58 Ant+BIO+Wetland
Month in 2019

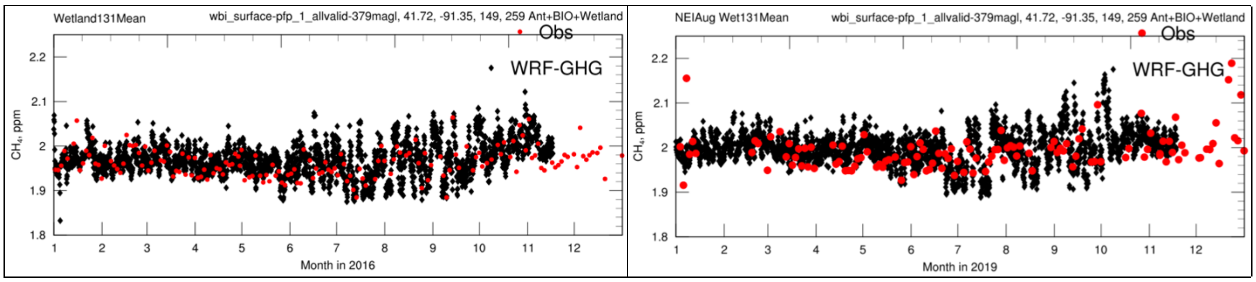

Wetland131Mean
mrc_surface-pfp_1_allvalid-61magl, 41.4662, -76.4188, 162, 362 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
mrc_surface-pfp_1_allvalid-61magl, 41.4662, -76.4188, 162, 362 Ant+BIO+Wetland
Month in 2019

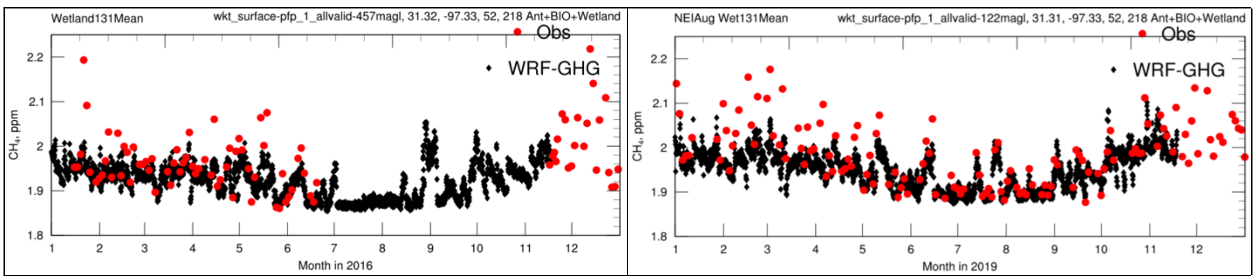

Wetland131Mean
msh_surface-pfp_1_allvalid-46magl, 41.6568, -70.4973, 174, 401 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
msh_surface-pfp_1_allvalid-46magl, 41.6568, -70.4973, 174, 401 Ant+BIO+Wetland
Month in 2019

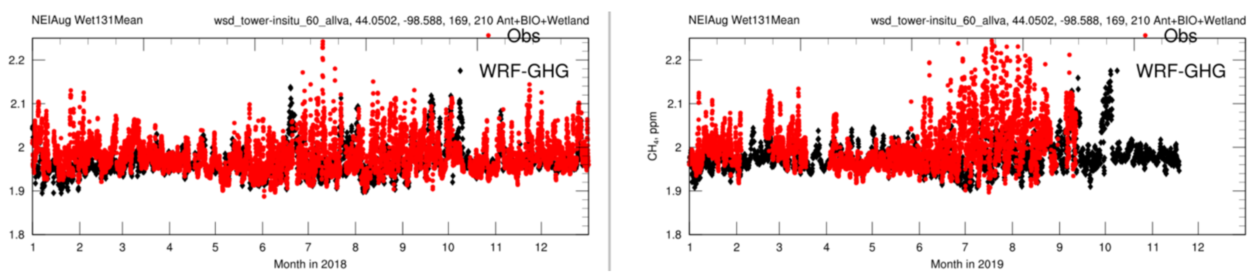

Wetland131Mean
nwr_surface-pfp_1_allvalid-3magl, 40.0531, -105.586, 135, 160 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
nwr_surface-pfp_1_allvalid-3magl, 40.0531, -105.586, 135, 160 Ant+BIO+Wetland
Month in 2019

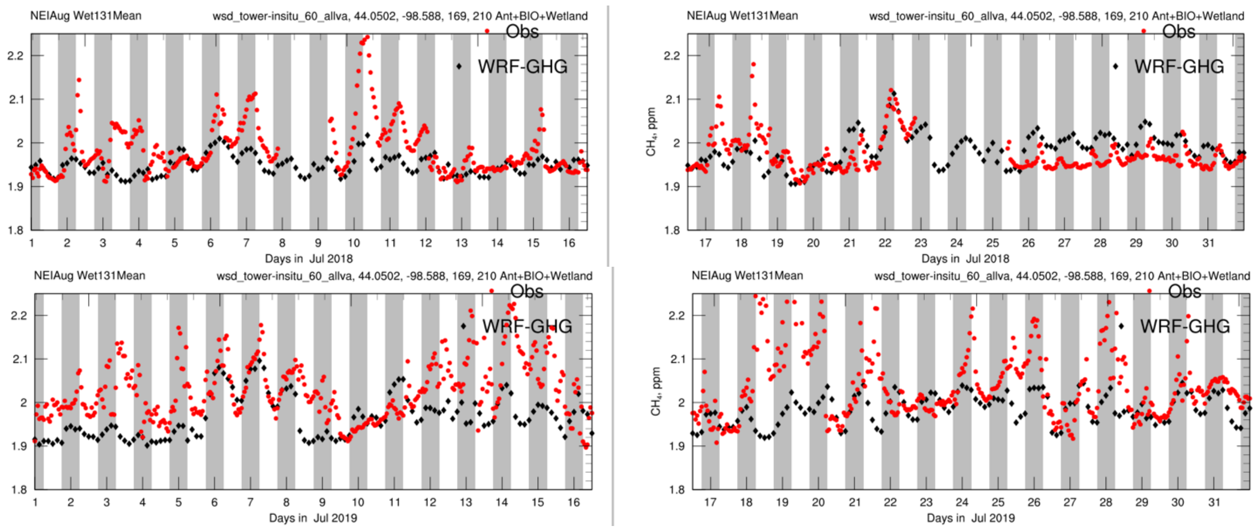

Wetland131Mean
sct_surface-pfp_1_allvalid-305magl, 33.406, -81.833, 81, 337 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
sct_surface-pfp_1_allvalid-305magl, 33.406, -81.833, 81, 337 Ant+BIO+Wetland
Month in 2019


Wetland131Mean
str_surface-pfp_1_allvalid-232magl, 37.75, -122.45, 137, 37 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
str_surface-pfp_1_allvalid-232magl, 37.75, -122.45, 137, 37 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019


Wetland131Mean
wbi_surface-pfp_1_allvalid-379magl, 41.72, -91.35, 149, 259 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
wbi_surface-pfp_1_allvalid-379magl, 41.72, -91.35, 149, 259 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019


Wetland131Mean
wkt_surface-pfp_1_allvalid-457magl, 31.32, -97.33, 52, 218 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2016
NEIAug Wet131Mean
wkt_surface-pfp_1_allvalid-122magl, 31.31, -97.33, 52, 218 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019

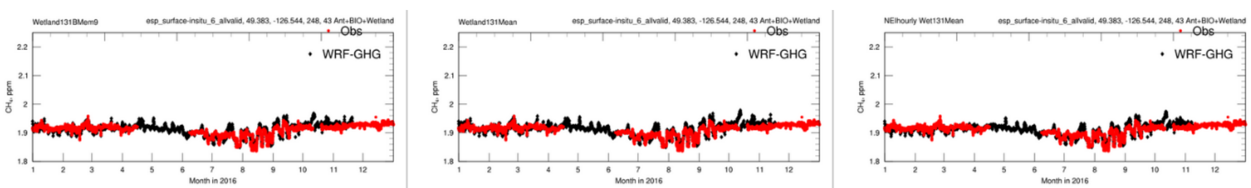

NEIAug Wet131Mean
wsd_tower-insitu_60_allva, 44.0502, -98.588, 169, 210 Ant+BIO+Wetland
Obs
WRF-GHG
Month in 2018
NEIAug Wet131Mean
wsd_tower-insitu_60_allva, 44.0502, -98.588, 169, 210 Ant+BIO+Wetland
Obs
WRF-GHG
CH4, ppm
Month in 2019



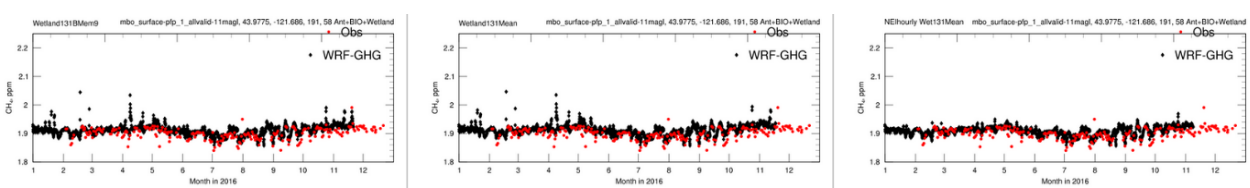
I compared WRF-GHG with the obspack surface-insitu CH4 dataset, and got mixed agreements, see 3 categories of agreements below:

- **Good agreements** at

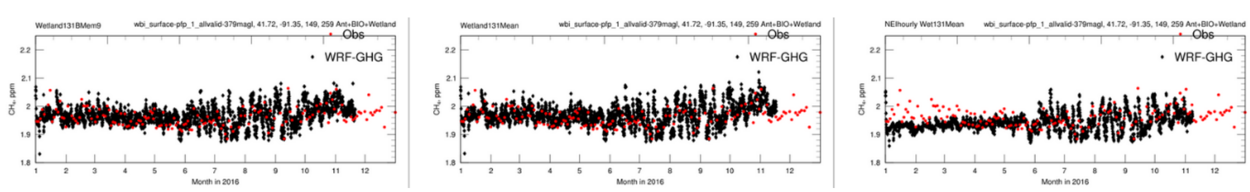
ESP: A Canada site near northwest corner of USA: (3 sensitivity simulations are shown below)



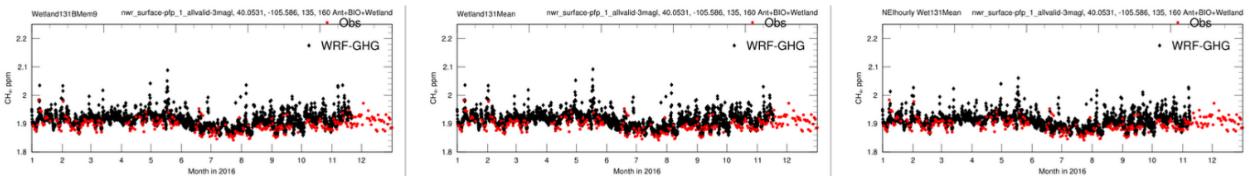
Mt. Bachelor Observatory, Oregon [MBO]:



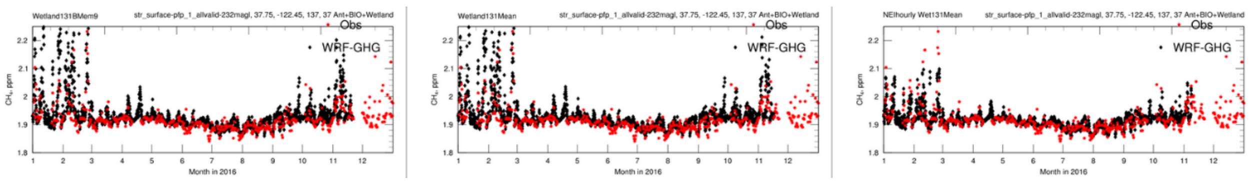
West Branch, Iowa, United States [WBI] :



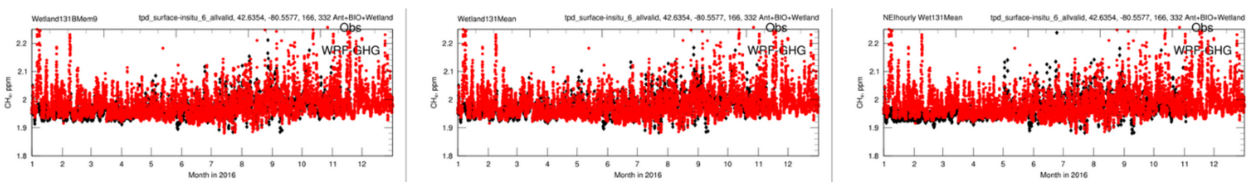
Niwot Ridge, Colorado [NWR]:

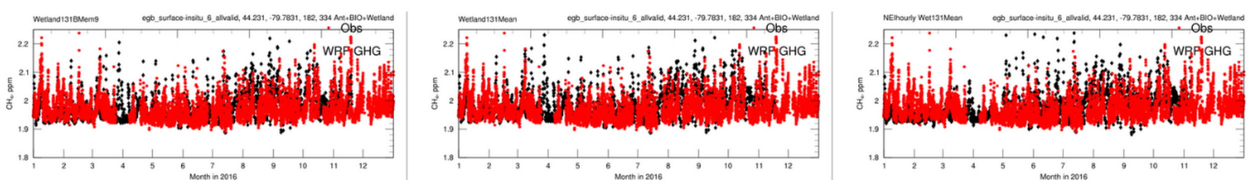


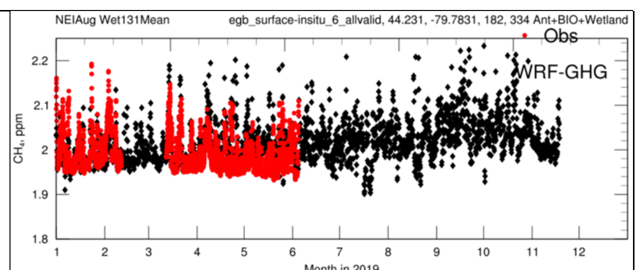
Sutro Tower, San Francisco[STR]:

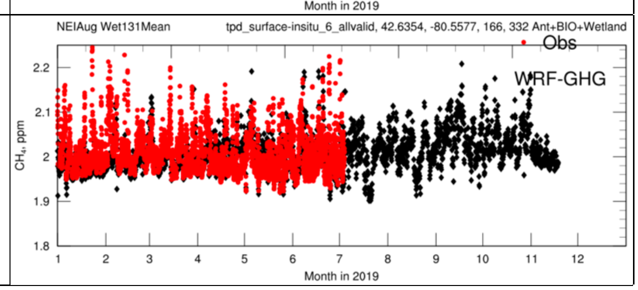


TPD, EGB around Great Lakes:



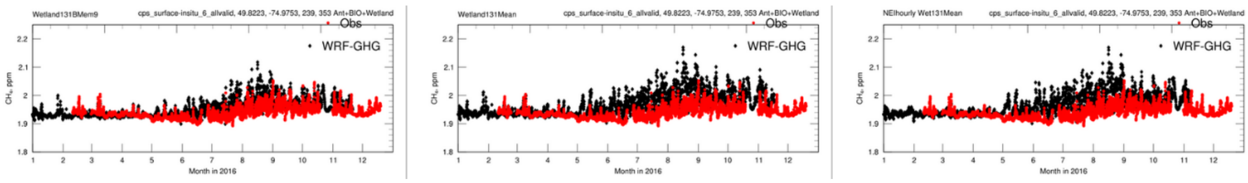




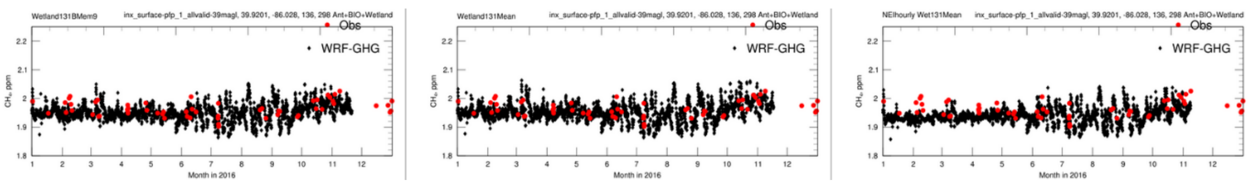


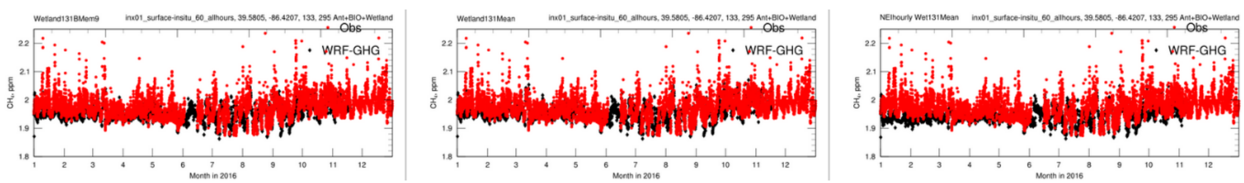
- **median agreement** at:

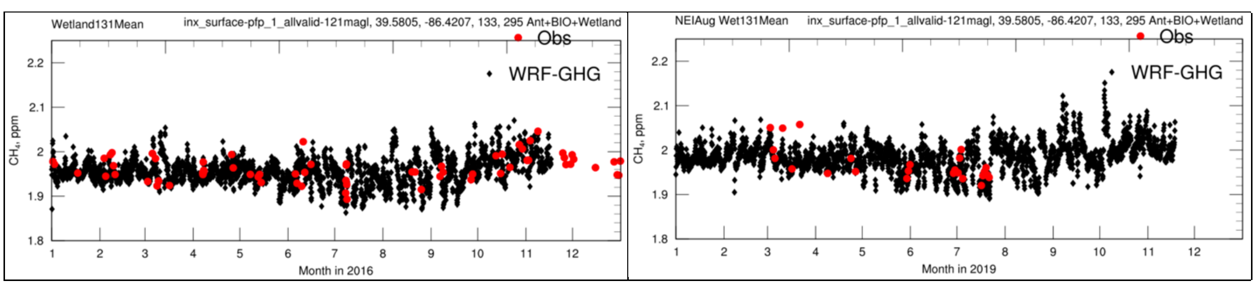
Canada Northeast:



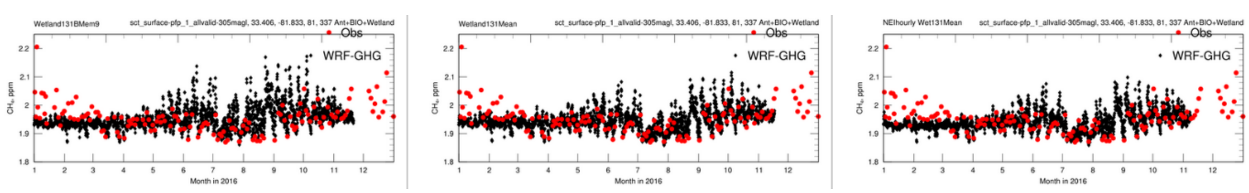
INFLUX (Indianapolis Flux Experiment), United States [INX]



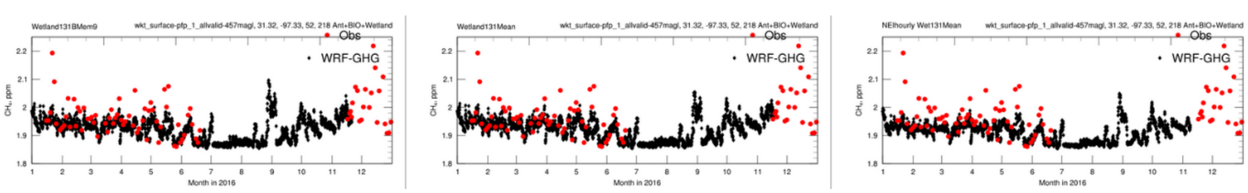




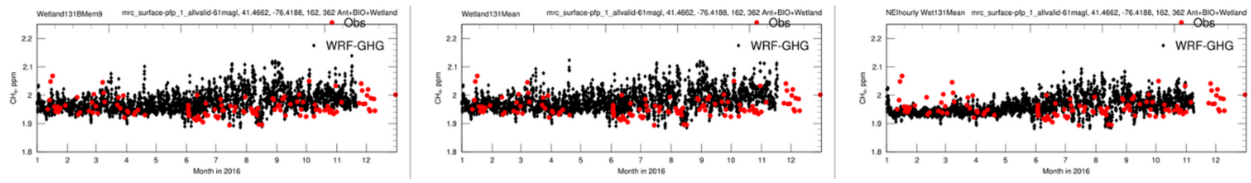
Beech Island, South Carolina [SCT]:



Moody, Texas, United States [WKT]:

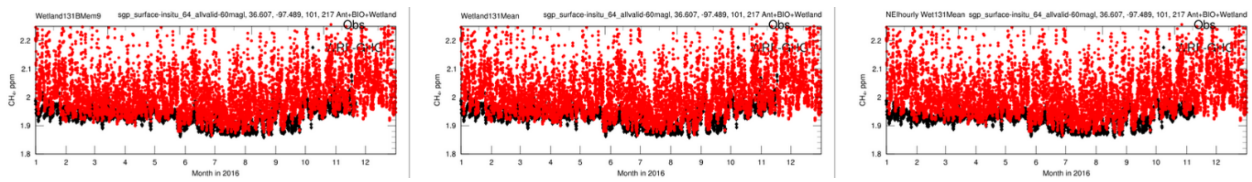


Marcellus Pennsylvania, United States [MRC]:

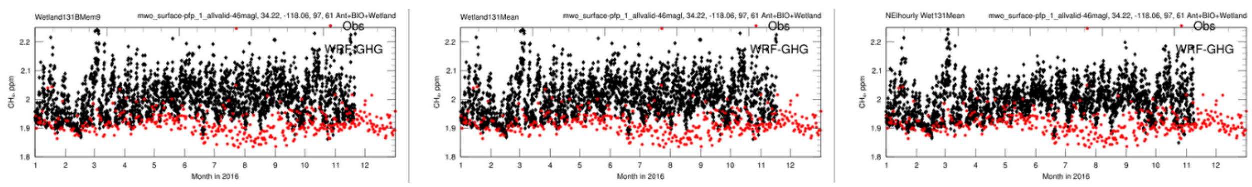


- **Large bias** at:

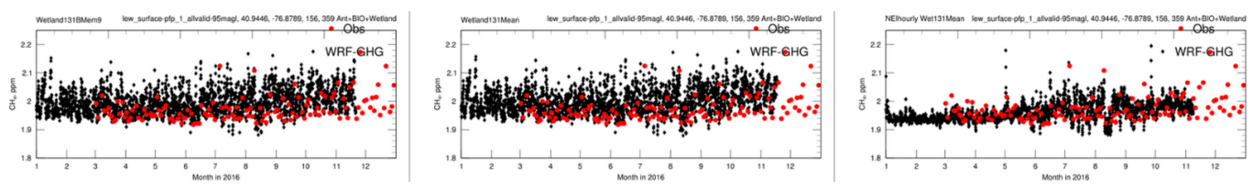
SGP:



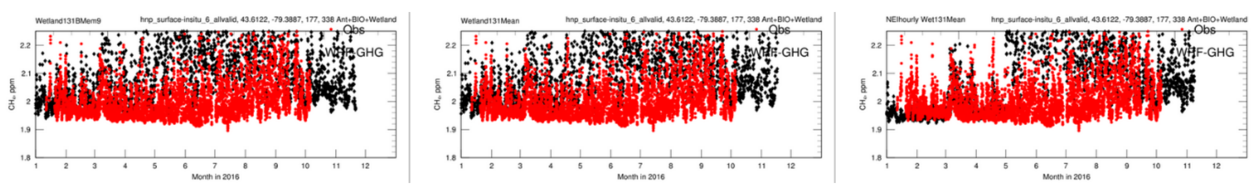
Mt. Wilson Observatory [MWO] around Los Angles



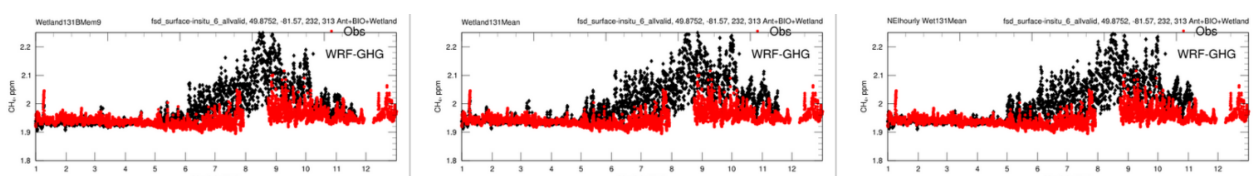
Lewisburg, Pennsylvania, United States [LEW]:



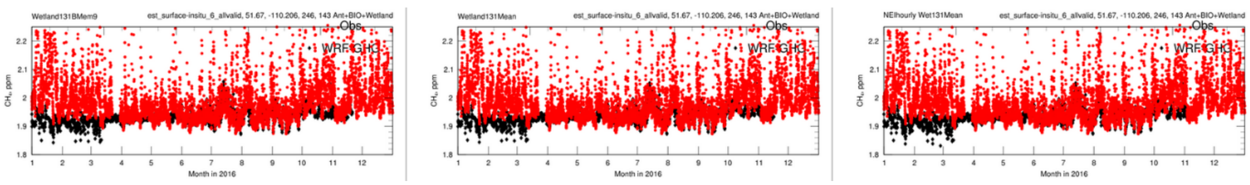
A lake side site around Toronto:



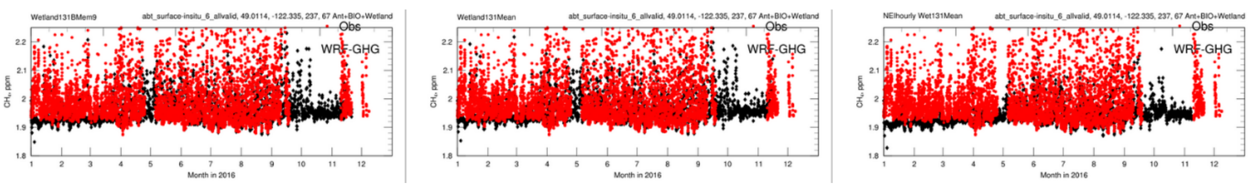
A Canada site over Wetland



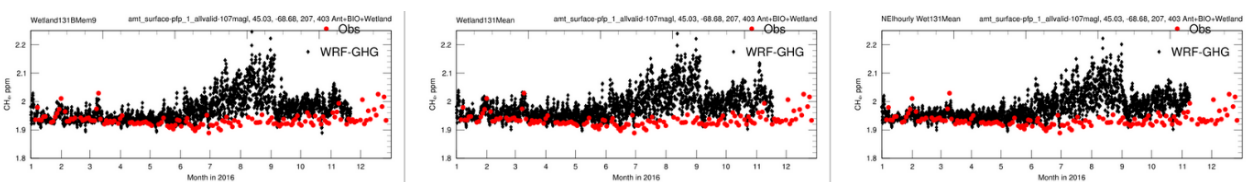
A Canada site over Wetland



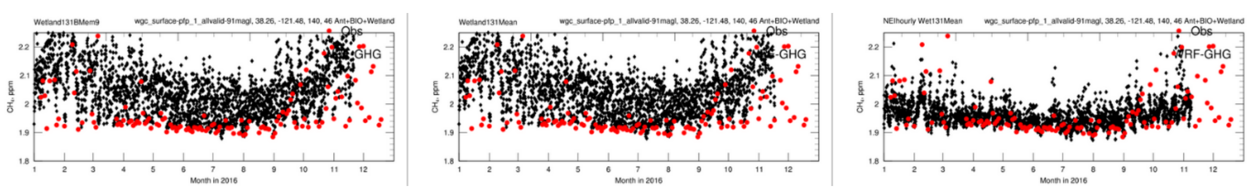
Canada Northwest:



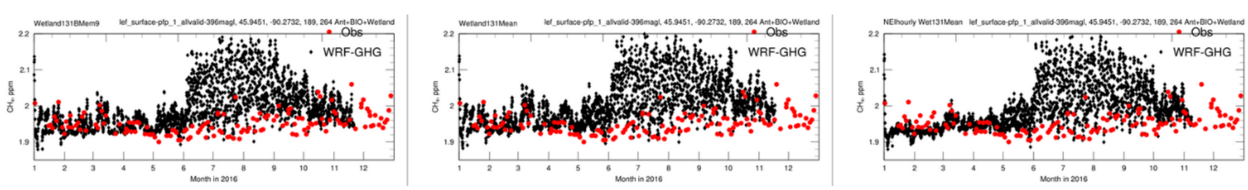
Argyle, Maine, United States [AMT]



Walnut Grove, California, United States [WGC]:



Park Falls, Wisconsin, United States [LEF]:



These comparison can help us identify the uncertainties in both anthropogenic emissions and wetland emissions

Xiao-Ming Hu

References:

Hu, X.-M., Gourdji, S. M., Davis, K. J., Wang, Q., Zhang, Y., Xue, M., . . . Crowell, S. M. R. (2021). Implementation of improved parameterization of terrestrial flux in WRF-VPRM improves the simulation of nighttime CO2 peaks and a daytime CO2 band ahead of a cold front. *Journal of Geophysical Research: Atmospheres*, e2020JD034362. https://doi.org/10.1029/2020JD034362

Hu, X. M., Crowell, S., Wang, Q., Zhang, Y., Davis, K. J., Xue, M., . . . DiGangi, J. P. (2020). Dynamical Downscaling of CO2 in 2016 Over the Contiguous United States Using WRF‐VPRM, a Weather‐Biosphere‐Online‐Coupled Model. *Journal of Advances in Modeling Earth Systems, 12*(4), e2019MS001875. 10.1029/2019ms001875