

# rain-days-anom-groupingA-wMPAS

January 24, 2022

## 1 Find rain days in a specified region, given 8 upper atm variables and respective Gridmet data.

This notebook calculates average rain on a 128x128 grid, it then averages the respective 8 upper atm variables.

- this version loads netcdf files directly via xarray
- “Gridmet data” can now be replaced with any model’s output

### 1.0.1 TODO items

- better graphs (i.e. include lat/lon scale)

```
[1]: from IPython import display
import numpy as np

#from skimage.metrics import structural_similarity as ssim
import copy
```

```
[2]: # load netcdf files directly via xarray
import xarray as xr
import matplotlib.pyplot as plt
import cartopy.crs as ccrs
import cartopy
```

## 2 Configuration

```
[3]: # Ordering: nRow ordering: obs, raw, RegCM4, WRF, MPAS, CNN, SDSM, KDDM, MBCn, ↳ LOCA
mpi_sigfiles=['/glade/work/mcginnis/DCA/data/gen/final/gridmet/hist/prec.hist.
→gridMET.obs.day.1980-2005.NAM-22i.SGP.x098.y36.nc',
'/glade/work/mcginnis/DCA/data/gen/final/mpi/hist/prec.hist.MPI-ESM-LR.raw.day.
→1980-2005.NAM-22i.SGP.x098.y36.nc',
'/glade/work/mcginnis/DCA/data/gen/final/mpi/rcp85/prec.rcp85.MPI-ESM-LR.raw.day.
→2075-2100.NAM-22i.SGP.x098.y36.nc',
```

```

'./glade/work/mcginnis/DCA/data/gen/final/regcm4/hist/prec.hist.MPI-ESM-LR.RegCM4.
→day.1980-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/regcm4/rcp85/prec.rcp85.MPI-ESM-LR.
→RegCM4.day.2075-2100.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/wrf/hist/prec.hist.MPI-ESM-LR.WRF.day.
→1980-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/wrf/rcp85/prec.rcp85.MPI-ESM-LR.WRF.day.
→2075-2100.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/mpas/hist/prec.hist.MPI-ESM-LR.MPAS.day.
→1980-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/mpas/rcp85/prec.rcp85.MPI-ESM-LR.MPAS.
→day.2075-2100.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/cnn/hist/prec.hist.MPI-ESM-LR.CNN.day.
→1980-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/cnn/rcp85/prec.rcp85.MPI-ESM-LR.CNN.day.
→2075-2100.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/sdsdm/hist/prec.hist.MPI-ESM-LR.SDSM.day.
→1976-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/sdsdm/rcp85/prec.rcp85.MPI-ESM-LR.SDSM.day.
→2070-2099.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/kddm/hist/prec.hist.MPI-ESM-LR.KDDM.day.
→1980-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/kddm/rcp85/prec.rcp85.MPI-ESM-LR.KDDM.
→day.2075-2100.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/mbcn/hist/prec.hist.MPI-ESM-LR.MBCn.day.
→1980-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/mbcn/rcp85/prec.rcp85.MPI-ESM-LR.MBCn.
→day.2075-2100.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/loca/hist/prec.hist.MPI-ESM-LR.LOCA.day.
→1980-2005.NAM-22i.SGP.x098.y36.nc',
'./glade/work/mcginnis/DCA/data/gen/final/loca/rcp85/prec.rcp85.MPI-ESM-LR.LOCA.
→day.2075-2100.NAM-22i.SGP.x098.y36.nc']

```

### 3 Compact configuration

```

[18]: sigdir = './glade/work/mcginnis/DCA/data/gen/final'
def model2absfilepath(mn, exp, x, y):
    if mn == 'obs' or mn == 'gridMET':
        mn = 'gridMET'
        filename = 'prec.{}.gridMET.{}.day.1980-2005.NAM-22i.SGP.x{}{}.y{}{}.nc'.
→format(exp, 'obs', x, y)
    elif mn == 'raw' or mn == 'mpi':
        mn = 'mpi'
        if exp == 'hist':

```

```

        filename = 'prec.{}.MPI-ESM-LR.{}.day.1980-2005.NAM-22i.SGP.x0{}.y{}.'
→nc'.format(exp, 'raw', x, y)
    elif exp == 'rcp85':
        filename = 'prec.{}.MPI-ESM-LR.{}.day.2075-2100.NAM-22i.SGP.x0{}.y{}.'
→nc'.format(exp, 'raw', x, y)
    else: print("Unknown experiment!")
elif mn == 'SDSM': # starts at 1976
    if exp == 'hist':
        filename = 'prec.{}.MPI-ESM-LR.{}.day.1976-2005.NAM-22i.SGP.x0{}.y{}.'
→nc'.format(exp, mn, x, y)
    elif exp == 'rcp85':
        filename = 'prec.{}.MPI-ESM-LR.{}.day.2070-2099.NAM-22i.SGP.x0{}.y{}.'
→nc'.format(exp, mn, x, y)
    else: print("Unknown experiment!")

    elif exp == 'hist':
        filename = 'prec.{}.MPI-ESM-LR.{}.day.1980-2005.NAM-22i.SGP.x0{}.y{}.nc'.
→format(exp, mn, x, y)
    elif exp == 'rcp85':
        filename = 'prec.{}.MPI-ESM-LR.{}.day.2075-2100.NAM-22i.SGP.x0{}.y{}.nc'.
→format(exp, mn, x, y)
    else: print("Unknown experiment!")
return sigdir + '/' + mn.lower() + '/' + exp + '/' + filename

```

### 3.0.1 Load model output data

[4]:

```

#####
## LOAD GRIDMET ##
#####
# 1980-1989
istart = 365
#ndays = 3653 # 1980-1989
ndays = 13515 # 1980-2016

dv1 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→prec128_gridmetA_1979-2016.nc')['prec'][istart:istart+ndays]
# dv2 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→tmax128_gridmetA_1979-2016.nc')['tmax'][istart:istart+ndays]
# dv3 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→tmin128_gridmetA_1979-2016.nc')['tmin'][istart:istart+ndays]
# dv4 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→uas128_gridmetA_1979-2016.nc')['uas'][istart:istart+ndays]
# dv5 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→vas128_gridmetA_1979-2016.nc')['vas'][istart:istart+ndays]
# dv6 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→huss128_gridmetA_1979-2016.nc')['huss'][istart:istart+ndays]

```

```
# dv7 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→rsds128_gridmetA_1979-2016.nc')['rsds'][istart:istart+ndays]
# dv8 = xr.open_dataset('/glade/work/dkorytin/srgan_data/
→miss128_gridmetB_1979-2016.nc')['miss'][istart:istart+ndays]
```

### 3.0.2 Load MPI UATM data

```
[5]: # # need this for ires the first time
# d='/glade/p/ral/risc/rmccrary/CMIP5_CORDEX/NAmerica/MPI-ESM-LR/native/
→historical/'
# mdv1 = xr.
→open_dataset(d+'U_MPI-ESM-LR_historical_r1i1p1_NAmerica_p850_19500101-20051231_dayavg_mpigrd
→nc')[['U']].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'), ↴
→lat=slice(23,56), lon=slice(-113,-80))
```

```
[6]: #####
## LOAD ERAI data: daily ##
#####
def load_uatm_erai():
    global mdv1,mdv2,mdv3,mdv4,mdv5,mdv6,mdv7,mdv8,mnvars

    # load eraionmpi
    #mndays = 11688      # 1979-2010
    mstart = 365
    mndays = 13515       # 1980-2016
    mnvars = 8*1
    mdv1 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/U850.ERA1.
→MPIGRID.1979-2018.nc')[['U']][mstart:mstart+mndays*1]
    mdv2 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/V850.ERA1.
→MPIGRID.1979-2018.nc')[['V']][mstart:mstart+mndays*1]
    mdv3 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/Q850.ERA1.
→MPIGRID.1979-2018.nc')[['Q']][mstart:mstart+mndays*1]
    mdv4 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/T700.ERA1.
→MPIGRID.1979-2018.nc')[['T']][mstart:mstart+mndays*1]
    mdv5 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/Z700.ERA1.
→MPIGRID.1979-2018.nc')[['Z']][mstart:mstart+mndays*1]
    mdv6 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/Z500.ERA1.
→MPIGRID.1979-2018.nc')[['Z']][mstart:mstart+mndays*1]
    mdv7 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/U250.ERA1.
→MPIGRID.1979-2018.nc')[['U']][mstart:mstart+mndays*1]
    mdv8 = xr.open_dataset('/glade/scratch/dkorytin/erai-on-mpigrid/V250.ERA1.
→MPIGRID.1979-2018.nc')[['V']][mstart:mstart+mndays*1]

    print("Days loaded", len(mdv7))
```

```
[7]: #####
## LOAD MPI      ##
#####

def load_uatm_mpi_hist():
    global mdv1,mdv2,mdv3,mdv4,mdv5,mdv6,mdv7,mdv8,mnvars

    mnvars = 8

    d='/glade/p/ral/risc/rmccrary/CMIP5_CORDEX/NAmerica/MPI-ESM-LR/native/
→historical/'

    mdv1 = xr.
    →open_dataset(d+'U_MPI-ESM-LR_historical_r1i1p1_NAmerica_p850_19500101-20051231_dayavg_mpigrd
→nc')[‘U’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

    mdv2 = xr.
    →open_dataset(d+'V_MPI-ESM-LR_historical_r1i1p1_NAmerica_p850_19500101-20051231_dayavg_mpigrd
→nc')[‘V’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

    mdv3 = xr.
    →open_dataset(d+'Q_MPI-ESM-LR_historical_r1i1p1_NAmerica_p850_19500101-20051231_dayavg_mpigrd
→nc')[‘Q’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

    mdv4 = xr.
    →open_dataset(d+'T_MPI-ESM-LR_historical_r1i1p1_NAmerica_p700_19500101-20051231_dayavg_mpigrd
→nc')[‘T’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

    mdv5 = xr.
    →open_dataset(d+'Z_MPI-ESM-LR_historical_r1i1p1_NAmerica_p700_19500101-20051231_dayavg_mpigrd
→nc')[‘Z’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

    mdv6 = xr.
    →open_dataset(d+'Z_MPI-ESM-LR_historical_r1i1p1_NAmerica_p500_19500101-20051231_dayavg_mpigrd
→nc')[‘Z’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

    mdv7 = xr.
    →open_dataset(d+'U_MPI-ESM-LR_historical_r1i1p1_NAmerica_p250_19500101-20051231_dayavg_mpigrd
→nc')[‘U’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

    mdv8 = xr.
    →open_dataset(d+'V_MPI-ESM-LR_historical_r1i1p1_NAmerica_p250_19500101-20051231_dayavg_mpigrd
→nc')[‘V’].sel(time=slice('1976-01-01T00:00:00', '2006-01-01T00:00:00'),l
→lat=slice(23,56), lon=slice(-113,-80))

def load_uatm_mpi_future():
    global mdv1,mdv2,mdv3,mdv4,mdv5,mdv6,mdv7,mdv8,mnvars
```

```

d='/glade/p/ral/risc/rmccrary/CMIP5_CORDEX/NAmerica/MPI-ESM-LR/native/rcp85/'

mnvars = 8
mdv1 = xr.
→open_dataset(d+'U_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p850_20060101-21001231_dayavg_mpigrid.
→nc')[‘U’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))
mdv2 = xr.
→open_dataset(d+'V_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p850_20060101-21001231_dayavg_mpigrid.
→nc')[‘V’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))
mdv3 = xr.
→open_dataset(d+'Q_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p850_20060101-21001231_dayavg_mpigrid.
→nc')[‘Q’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))
mdv4 = xr.
→open_dataset(d+'T_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p700_20060101-21001231_dayavg_mpigrid.
→nc')[‘T’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))
mdv5 = xr.
→open_dataset(d+'Z_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p700_20060101-21001231_dayavg_mpigrid.
→nc')[‘Z’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))
mdv6 = xr.
→open_dataset(d+'Z_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p500_20060101-21001231_dayavg_mpigrid.
→nc')[‘Z’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))
mdv7 = xr.
→open_dataset(d+'U_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p250_20060101-21001231_dayavg_mpigrid.
→nc')[‘U’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))
mdv8 = xr.
→open_dataset(d+'V_MPI-ESM-LR_rcp85_r1i1p1_NAmerica_p250_20060101-21001231_dayavg_mpigrid.
→nc')[‘V’].sel(time=slice(‘2006-01-01T00:00:00’, ‘2101-01-01T00:00:00’), ↴
→lat=slice(23,56), lon=slice(-113,-80))

#load_uatm_mpi_future()

```

## 4 Averaging code

```
[8]: ##########
## UATM averages ##
###############
```

```

def calc_uatm_average(mpr_min, mpr_max, rainsignal, ymin, ymax):
    # global inputs: dv[1-8], mdv[1-8], mnvars
    mnvars = 8

    # initialize accumulators
    indices = []
    distribution = []
    raw_ires = len(mdv1[0])
    raininput = np.zeros((mnvars, raw_ires, raw_ires))
    raincount = 0

    for ii in range(0,len(rainsignal)):
        mpr = rainsignal[ii]

        # May = 5
        if mpr["time.month"] == 5 and mpr["time.year"] >= ymin and mpr["time.
→year"] < ymax:

            if mpr >= mpr_min and mpr < mpr_max:
                distribution.append(mpr)
                indices.append(ii)

            #mpr = dv1[ii].sel(lat=slice(32.125,38.125), lon=slice(-101.
→875,-93.875)).mean()

            # find matching input sample
            #ot= dv1[ii-1]['time']
            ot = str(np.array(mpr['time']))

            mdv1.sel(time=ot,method='nearest')
            isample = [mdv1.sel(time=ot,method='nearest'),mdv2.
→sel(time=ot,method='nearest'),mdv3.sel(time=ot,method='nearest'),mdv4.
→sel(time=ot,method='nearest'),mdv5.sel(time=ot,method='nearest'),mdv6.
→sel(time=ot,method='nearest'),mdv7.sel(time=ot,method='nearest'),mdv8.
→sel(time=ot,method='nearest')]
            #ot= dv1[ii]['time']
            #assert ot["time.day"]==isample[0]['time.day'], "Days are not
→equal"
            isample = np.array(isample)

            raininput += isample
            raincount += 1

    raininput /= raincount
    #print("days:", raincount)

```

```
    return raininput, raincount, distribution, indices
```

## 5 Plot routines

```
[9]: import matplotlib.pyplot as plt
import cartopy.crs as ccrs
import cartopy
import cartopy.feature as cfeature

# plot average rain inputs
def plot_8v_clim(isample, modelname, vmin, vmax):
    varmames = ['U850', 'V850', 'Q850', 'T700', 'Z700', 'Z500', 'U250', 'V250']
    units = ['m/s', 'm/s', 'kg/kg', 'K', 'mb', 'mb', 'm/s', 'm/s']
    cmaps = ['PiYG', 'PuOr', 'cividis', 'inferno', 'viridis', 'viridis', 'PiYG', 'PuOr']

    fig, axarr = plt.subplots(1, 8, figsize = (20,20))
    for ii in range(8):
        plot = axarr[ii].imshow(isample[ii][:-1,:], vmin=vmin[ii], vmax=vmax[ii], cmap=cmaps[ii])
        cbar = fig.colorbar(plot, ax=axarr[ii], orientation="horizontal", fraction=0.046, pad=0.016)
        cbar.set_label(units[ii])
        axarr[ii].set_title(varmames[ii])
    plt.suptitle(modelname, y=0.29, fontsize=16)
    plt.show()

    varmames = ['U850', 'V850', 'Q850', 'T700', 'Z700', 'Z500', 'U250', 'V250']
    units = ['m/s', 'm/s', 'kg/kg', 'K', 'mb', 'mb', 'm/s', 'm/s']
    #cmaps = ['PiYG', 'PuOr', 'cividis', 'inferno', 'viridis', 'viridis', 'PiYG', 'PuOr']
    cmaps = ['PiYG', 'PuOr', 'BrBG', 'RdBu_r', 'Spectral', 'Spectral', 'PiYG', 'PuOr']

    # ALL Ranges centered on zero for U, V
    for ii in range(8):
        vmin[ii] = -max(abs(vmin[ii]), abs(vmax[ii]))
        vmax[ii] = max(abs(vmin[ii]), abs(vmax[ii]))

    fig, axarr = plt.subplots(1, 8, figsize = (20,20), subplot_kw={'projection':ccrs.PlateCarree()})
```

```

lon = mdv1[0].lon
lat = mdv1[0].lat

for ii in range(8):

    #axarr[ii].set_title("Subplot row", fontsize=16)
    axarr[ii].coastlines()
    axarr[ii].add_feature(cfeature.STATES)
    img_extent = (lon.min(), lon.max(), lat.min(), lat.max())
    plot = axarr[ii].imshow(isample[ii][:-1,:], vmin=vmin[ii],  

    →vmax=vmax[ii], cmap=cmaps[ii], origin='upper', extent=img_extent,  

    →transform=ccrs.PlateCarree())
    #plot = axarr[ii].imshow(isample[ii][:-1,:], vmin=vmin[ii],  

    →vmax=vmax[ii], cmap=cmaps[ii])
    cbar = fig.colorbar(plot, ax=axarr[ii], orientation="horizontal",  

    →fraction=0.046, pad=0.016)
    cbar.set_label(units[ii])
    axarr[ii].set_title(varmames[ii])

plt.suptitle(modelname, y=0.29, fontsize=16)
plt.show()

def plot_8v_autoscale(isample, modelname):
    varmames = ['U850', 'V850', 'Q850', 'T700', 'Z700', 'Z500', 'U250', 'V250']
    units = ['m/s', 'm/s', 'kg/kg', 'K', 'mb', 'mb', 'm/s', 'm/s']
    #cmaps = ['PiYG', 'PuOr', 'cividis', 'inferno', 'viridis', 'viridis',  

    →'PiYG', 'PuOr']
    cmaps = ['PiYG', 'PuOr', 'BrBG', 'RdBu_r', 'Spectral', 'Spectral', 'PiYG',  

    →'PuOr']

    # autoscale
    vmin = [isample[ii].min() for ii in range(8)]
    vmax = [isample[ii].max() for ii in range(8)]

#    # Use 0 as minimum value for Q
#    vmin[2] = 0.

    # Ranges centered on zero for U, V
    vmin[0] = -max(abs(vmin[0]), abs(vmax[0]))
    vmax[0] = max(abs(vmin[0]), abs(vmax[0]))
    vmin[1] = -max(abs(vmin[1]), abs(vmax[1]))
    vmax[1] = max(abs(vmin[1]), abs(vmax[1]))

    vmin[6] = -max(abs(vmin[6]), abs(vmax[6]))
    vmax[6] = max(abs(vmin[6]), abs(vmax[6]))

```

```

vmin[7] = -max(abs(vmin[7]), abs(vmax[7]))
vmax[7] = max(abs(vmin[7]), abs(vmax[7]))


fig, axarr = plt.subplots(1, 8, figsize = (20,20), subplot_kw={'projection':ccrs.PlateCarree()})
lon = mdv1[0].lon
lat = mdv1[0].lat

for ii in range(8):

    #axarr[ii].set_title("Subplot row", fontsize=16)
    axarr[ii].coastlines()
    axarr[ii].add_feature(cfeature.STATES)
    img_extent = (lon.min(), lon.max(), lat.min(), lat.max())
    plot = axarr[ii].imshow(isample[ii][:-1,:], vmin=vmin[ii], vmax=vmax[ii], cmap=cmaps[ii], origin='upper', extent=img_extent, transform=ccrs.PlateCarree())
    #plot = axarr[ii].imshow(isample[ii][:-1,:], vmin=vmin[ii], vmax=vmax[ii], cmap=cmaps[ii])
    cbar = fig.colorbar(plot, ax=axarr[ii], orientation="horizontal", fraction=0.046, pad=0.016)
    cbar.set_label(units[ii])
    axarr[ii].set_title(varnames[ii])

plt.suptitle(modelname, y=0.29, fontsize=16)
plt.show()

```

### 5.0.1 Calculate historical average (to be subtracted away later)

[11]:

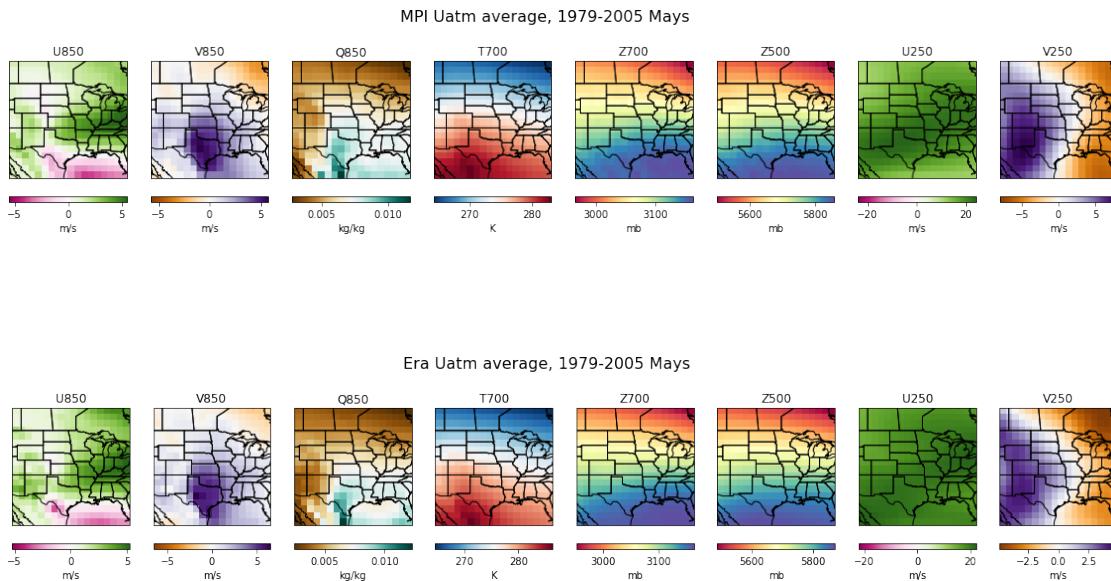
```
# find average for ALL historical MPI days
load_uatm_mpi_hist()
sigfile = mpi_sigfiles[0]      # doesn't matter which sigfile b/c we consider all
    →precip 0-9999
rainsignal = xr.open_dataset(sigfile)['prec']
allinput, allcount, alldistribution, dryindices = calc_uatm_average(0, 9999,
    →rainsignal, 1979, 2005)
```

[12]:

```
# find average for ALL Eraint days
load_uatm_erai()
sigfile = mpi_sigfiles[0]      # doesn't matter which sigfile b/c we consider all
    →precip 0-9999
rainsignal = xr.open_dataset(sigfile)['prec']
era_allinput, era_allcount, era_alldistribution, dryindices =
    →calc_uatm_average(0, 9999, rainsignal, 1979, 2005)
```

Days loaded 13515

```
[13]: # plot average all hist Mays: MPI & Era
plot_8v_autoscale(allinput, 'MPI Uatm average, 1979-2005 Mays')
plot_8v_autoscale(era_allinput, 'Era Uatm average, 1979-2005 Mays')
```



## 6 Run over all models

```
[14]: # POSTAGE STAMP LAYOUT
import matplotlib.pyplot as plt
from os.path import basename
from mpl_toolkits.axes_grid1.inset_locator import inset_axes
import matplotlib.ticker as ticker
from matplotlib import ticker

import warnings
warnings.filterwarnings("ignore")

def plot_models_group_drymoistwet(sigfiles, vmin, vmax):

    # CLIM
    # ALL Ranges centered on zero for U, V
    for ii in range(8):
        vmin[ii] = -max(abs(vmin[ii]), abs(vmax[ii]))
        vmax[ii] = max(abs(vmin[ii]), abs(vmax[ii]))
```

```

# plots
for sigfile in sigfiles:

    # load UATM and signal file
    if sigfile.lower().find('obs') >= 0:
        load_uatm_erai()
    elif sigfile.lower().find('hist') >= 0:
        load_uatm_mpi_hist()
    elif sigfile.lower().find('rcp85') >= 0:
        load_uatm_mpi_future()
    else:
        print ("ERROR: neither hist or rcp85 found")
    rainsignal = xr.open_dataset(sigfile)['prec']

    # plot
    counts = [0,0,0]

    #fig, axarr = plt.subplots(nrows=3, ncols=8, figsize = (10,10*(3/8.+0.
    →0)), gridspec_kw={'hspace': 0.0, 'wspace': 0.0, 'height_ratios':[1,1,1.3]})
    fig, axarr = plt.subplots(nrows=3, ncols=8, figsize = (20,20*(3/8.+0.
    →0)), subplot_kw={'projection': ccrs.PlateCarree()}, gridspec_kw={'hspace': 0.
    →0, 'wspace': 0.0, 'height_ratios':[1,1,1.313]})

    lon = mdv1[0].lon
    lat = mdv1[0].lat

    for jj, mpr_min, mpr_max, label in [[0, 0., 0.254, 'Dry'], [1, 0.254, 3.
    →, 'Moist'], [2, 3., 9999., 'Wet']]:
        # calc avg atm for criteria
        avginput, count, distribution, indices = calc_uatm_average(mpr_min, mpr_max, rainsignal, -9999, 9999)

        # subtract clim
        if sigfile.lower().find('obs') >= 0:
            avginput-=era_allinput # era
        else:
            avginput-=allinput # mpi

        # use percentages instead of counts (2021-10-26)
        #counts[jj] = count
        allavginput, allcount, alldistribution, allindices = calc_uatm_average(0, 9999, rainsignal, -9999, 9999)
        counts[jj] = count/allcount

```

```

varnames = ['U850', 'V850', 'Q850', 'T700', 'Z700', 'Z500', 'U250', ↴
    'V250']

units = ['m/s', 'm/s', 'kg/kg', 'K', 'mb', 'mb', 'm/s', 'm/s']
#cmaps = ['PiYG', 'PuOr', 'cividis', 'inferno', 'viridis', ↴
    'viridis', 'PiYG', 'PuOr']

#cmaps = ['PiYG', 'PuOr', 'cubehelix_r', 'inferno', 'terrain', ↴
    'Spectral', 'brg', 'PuOr'] #ABS
cmaps = ['PiYG', 'PuOr', 'BrBG', 'RdBu_r', 'Spectral', 'Spectral', ↴
    'PiYG', 'PuOr'] # CLIM

for ii in range(8):
    axarr[jj,ii].coastlines()
    axarr[jj,ii].add_feature(cfeature.STATES)
    img_extent = (lon.min(), lon.max(), lat.min(), lat.max())

    #plot = axarr[jj,ii].imshow(avginput[ii][:-1,:], vmin=vmin[ii], ↴
    vmax=vmax[ii], cmap=cmaps[ii])
    plot = axarr[jj,ii].imshow(avginput[ii][:-1,:], vmin=vmin[ii], ↴
    vmax=vmax[ii], cmap=cmaps[ii], origin='upper', extent=img_extent, ↴
    transform=ccrs.PlateCarree())

    # show y tics on first column
    if ii==0:
        axarr[jj,ii].get_yaxis().set_visible(True)
        axarr[jj,ii].tick_params(labelsize='xx-small')

    # We need to draw the canvas, otherwise the labels won't be ↴
    positioned and
    # won't have values yet.
    fig.canvas.draw()

    # lat range: 56 to 23
    labels = [item.get_text() for item in axarr[jj,ii]. ↴
    get_yticklabels()]
    #labels = ['56', '46', '36', '26']
    axarr[jj,ii].set_yticklabels(labels)

## show y labels on last column
#if ii==7:
    ##axarr[jj,ii].get_yaxis().set_visible(True)
    ##axarr[jj,ii].tick_params(labelsize='xx-small')
    #

```

```

#cbar = fig.colorbar(plot, ax=axarr[jj,ii],  

→orientation="horizontal", fraction=0.03, pad=0.2)  

#  

##ax.set_ylabel("Label", rotation=270)  

#  

##cbar = fig.colorbar(plot, ax=axarr[jj,ii],  

→orientation="vertical", fraction=0.046, pad=0.016)  

#cbar.set_label('dry', rotation=90, size='xx-small')  

#cbar.ax.tick_params(labelsize='xx-small')

if ii>=1:  

    axarr[jj,ii].get_yaxis().set_visible(False)  

    axarr[jj,ii].tick_params(labelsize='xx-small')

if jj == 0:  

    axarr[jj,ii].set_title(varnames[ii])  

    axarr[jj,ii].get_xaxis().set_visible(False)  

    axarr[jj,ii].tick_params(labelsize='xx-small')

if jj==1:  

    axarr[jj,ii].get_xaxis().set_visible(False)  

#axarr[jj,ii].tick_params(labelsize='xx-small')

# show custom tics on bottom row: lon=slice(-113,-80)
if jj==2:  

    axarr[jj,ii].get_xaxis().set_visible(True)  

    axarr[jj,ii].tick_params(labelsize='xx-small')

# We need to draw the canvas, otherwise the labels won't be  

→positioned and  

# won't have values yet.  

fig.canvas.draw()

labels = [item.get_text() for item in axarr[jj,ii].  

→get_xticklabels()]
#labels[1] = '-113'  

#labels[2] = '-103'  

#labels[3] = '-93'  

##labels[4] = '-83'  

axarr[jj,ii].set_xticklabels(labels)

```

```

# colorbar only on 3rd postage stamp
if jj==2:
    # use scientific notation on 3rd column colorbar only
    if ii == 2:
        def fmt(x, pos):
            a, b = '{:.1e}'.format(x).split('e')
            b = int(b)
            return r'${}e{}$'.format(a, b)
    cbar = fig.colorbar(plot, ax=axarr[jj,ii],  

→orientation="horizontal", fraction=0.0385, pad=0.2, format=ticker.  

→FuncFormatter(fmt))

        #cbar = fig.colorbar(plot, ax=axarr[jj,ii],  

→orientation="horizontal", fraction=0.0385, pad=0.2, format='%.0e')  

→#format=ticker.FuncFormatter(fmt))

        #cbar.set_ticks([0.2, 0.4, 0.6, 0.8])
        #cbar.set_ticklabels(["A", "B", "C", "D"])
        tick_locator = ticker.MaxNLocator(nbins=4)
        cbar.locator = tick_locator
        cbar.update_ticks()

    else:
        cbar = fig.colorbar(plot, ax=axarr[jj,ii],  

→orientation="horizontal", fraction=0.0385, pad=0.2, format=None)

        cbar.set_label(units[ii], size='xx-small')
        cbar.ax.tick_params(labelsize='xx-small')

# row titles
if jj==0:
    #text = axarr[jj,0].text(-.1,0.5,'dry:'+str(counts[0]), size=12,
    #verticalalignment='center_baseline', rotation=90)
    plt.figtext(0.09, 0.75, 'Dry:' + str(int(counts[jj]*100)) + '%',  

→fontsize=11, rotation=90)

    # row titles
if jj==1:
    #text = axarr[jj,1].text(1.0,0.6,'moist:' + str(counts[1]),  

→size=12,
    #verticalalignment='center_baseline', rotation=270)
    plt.figtext(0.09, 0.5, 'Moist:' + str(int(counts[jj]*100)) + '%',  

→fontsize=11, rotation=90)

# row titles

```

```

if jj==2:
    #text = axarr[jj,7].text(1.0,1.6,'wet:'+str(counts[2]), size=12,
    #verticalalignment='center_baseline', rotation=90)
    plt.figtext(0.092, 0.25, 'Wet:' + str(int(counts[jj]*100)) + '%', fontweight='bold', fontsize=11, rotation=90)

    # row title
    sigfilename = basename(sigfile)
    #print ("days:", count, " model:", sigfilename)
    rowtitle = ' '.join(sigfilename.split('.')[0:4]) # + ' Count:' + str(counts)
    fig.suptitle(rowtitle.upper(), y=1.05, fontsize=14)

    #plt.subplots_adjust(left=0.1, right=0.9, bottom=0.1, top=0.9, wspace=0, hspace=0)
    #plt.subplots_adjust(wspace=0, hspace=0)
    #plt.subplots_adjust(wspace=0.0, hspace=0, right=0.7)

    plt.show()

```

### 6.0.1 Hist

```
[24]: # find max/min for each variable accross ALL hist files
#sigfiles_hist = list(filter(lambda line: 'hist' in line, mpi_sigfiles))
sigfiles_hist = [model2absfilepath(ff, 'hist', 98, 36) for ff in
                  ['obs', 'raw', 'RegCM4', 'WRF', 'MPAS', 'CNN', 'SDSM', 'KDDM', 'MBCn', 'LOCA']]


# find min/max values for entire sigfiles set
vmin = 9999*np.ones(8)
vmax = -9999*np.ones(8)
for sigfile in sigfiles_hist:

    # skip mpas in max/min range (it's too extreme)
    if sigfile.lower().find('mpas') >= 0:
        continue
    else:
        # load UATM and signal file
        if sigfile.lower().find('obs') >= 0:
            load_uatm_erai()
        elif sigfile.lower().find('hist') >= 0:
            load_uatm_mpi_hist()
        elif sigfile.lower().find('rcp85') >= 0:

```

```

        load_uatm_mpi_future()
    else:
        print ("ERROR: neither hist or rcp85 found")
    rainsignal = xr.open_dataset(sigfile)['prec']

    for mpr_min, mpr_max in [(0,0.254), (0.254, 3.0), (3.0, 9999.0)]:
        avginput, count, distribution, indices = calc_uatm_average(mpr_min, mpr_max, rainsignal, -9999, 9999)

        # subtract clim
        if sigfile.lower().find('obs') >= 0:
            avginput-=era_allinput # era
        else:
            avginput-=allinput # mpi

    vmin = [min(avginput[ii].min(),vmin[ii]) for ii in range(8)]
    vmax = [max(avginput[ii].max(),vmax[ii]) for ii in range(8)]

```

Days loaded 13515

```
[25]: #vmin = [-2.860119676676735, -4.102923563004548, -0.0017967277242531702, -2.
      →3120241534937804, -22.72752843471426, -36.628780639855904, -6.612512401846351, →
      →-6.854882577848712]
#vmax = [2.0965965940672997, 4.113926477610356, 0.0016094864748026193, 1.
      →5190344257618449, 27.117413894014135, 39.87112130642436, 5.569866144558251, 8.
      →797318717295934]
```

```
[26]: print(vmin)
print(vmax)
```

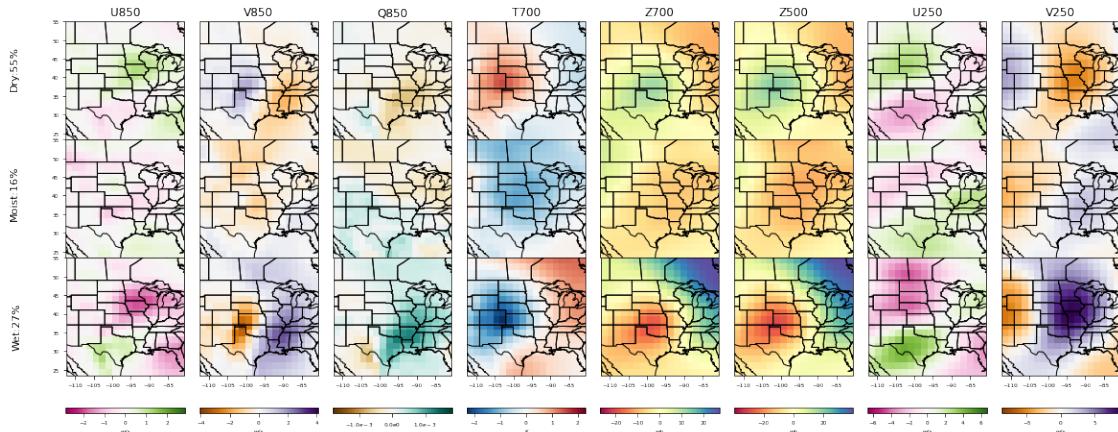
```
[-2.860119676676735, -4.102923563004548, -0.0017967277242531702,
-2.3120241534937804, -22.72752843471426, -36.628780639855904,
-6.612512401846351, -6.854882577848712]
[2.0965965940672997, 4.113926477610356, 0.0016094864748026193,
1.5190344257618449, 27.117413894014135, 39.87112130642436, 5.569866144558251,
8.797318717295934]
```

```
[27]: #sigfiles_hist = list(filter(lambda line:'hist' in line, mpi_sigfiles))
sigfiles_hist = [model2absfilepath(ff, 'hist', 98, 36) for ff in
      →['obs','raw','RegCM4','WRF','MPAS','CNN','SDSM','KDDM','MBCn','LOCA']]
```

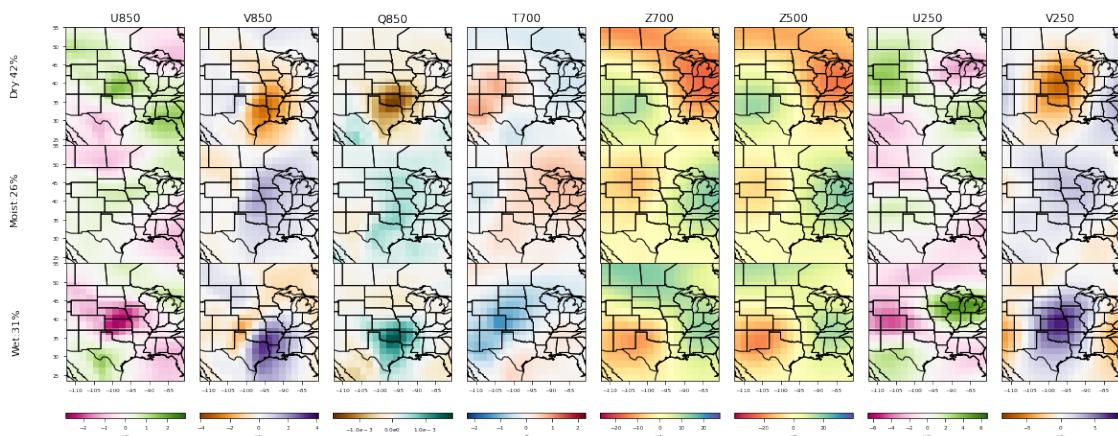
```
plot_models_group_drymoistwet(sigfiles_hist, vmin, vmax)
```

Days loaded 13515

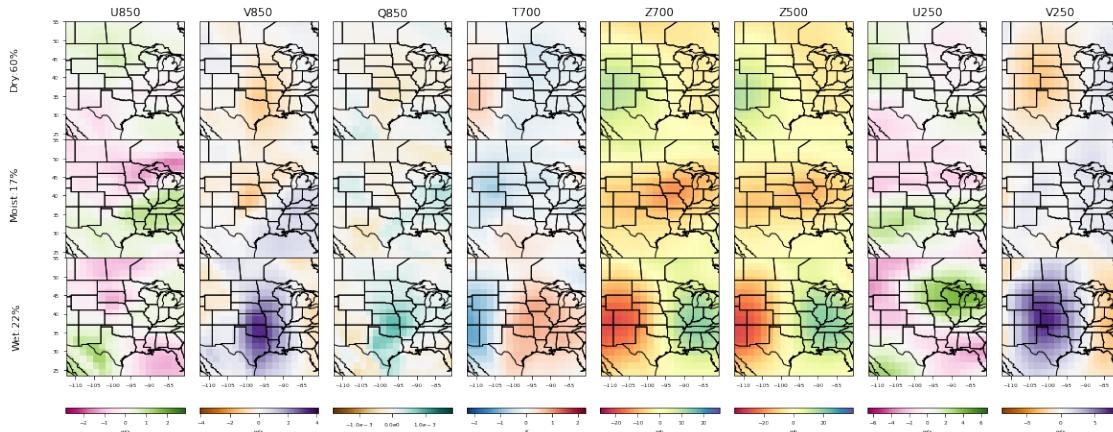
PREC HIST GRIDMET OBS



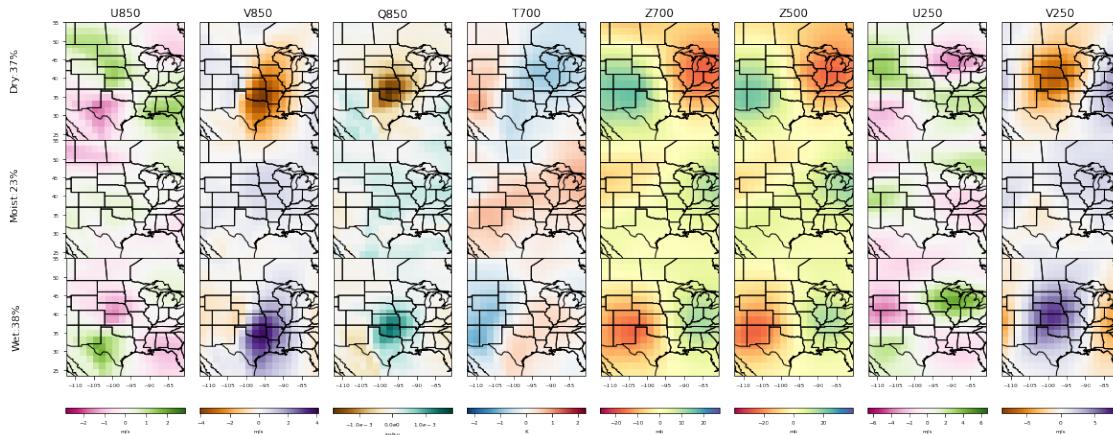
PREC HIST MPI-ESM-LR RAW



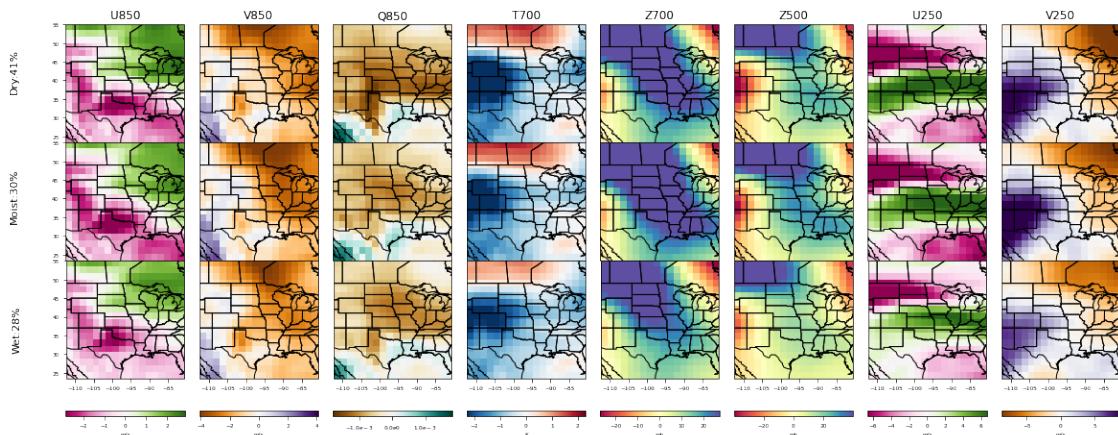
PREC HIST MPI-ESM-LR REGCM4



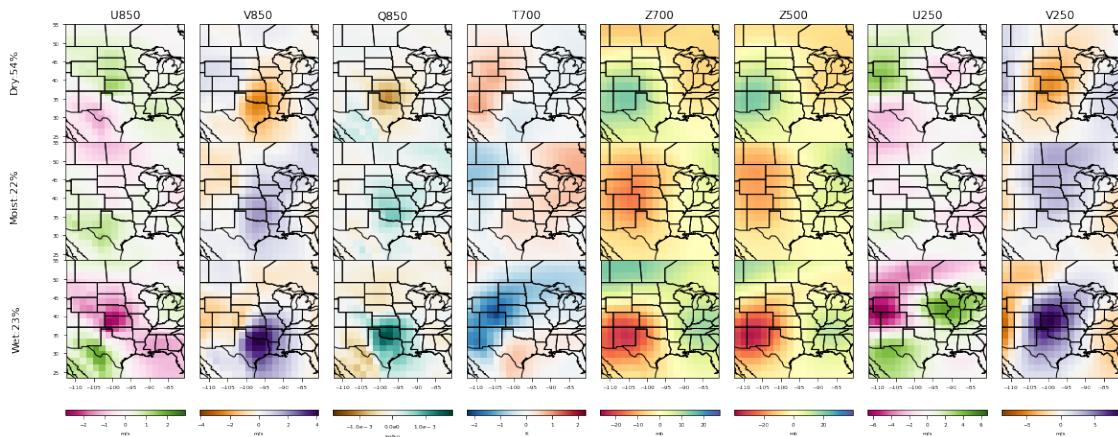
PREC HIST MPI-ESM-LR WRF



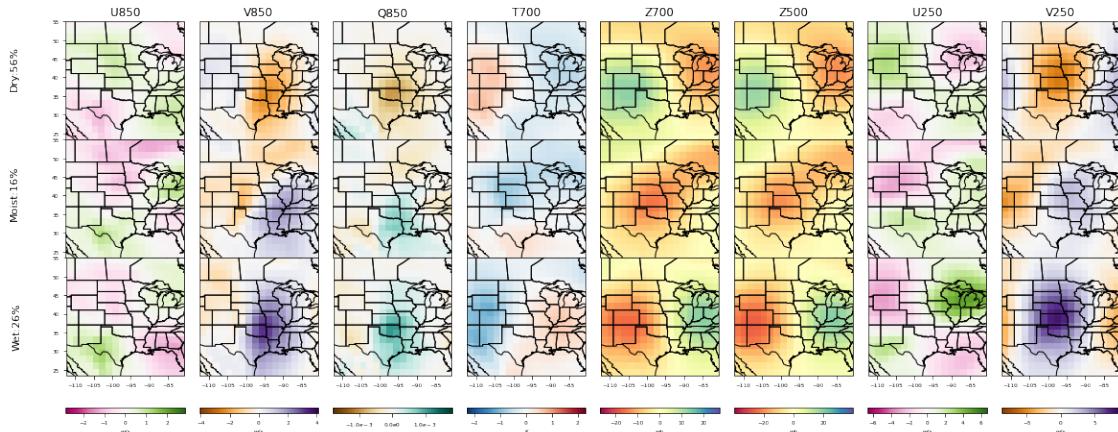
PREC HIST MPI-ESM-LR MPAS



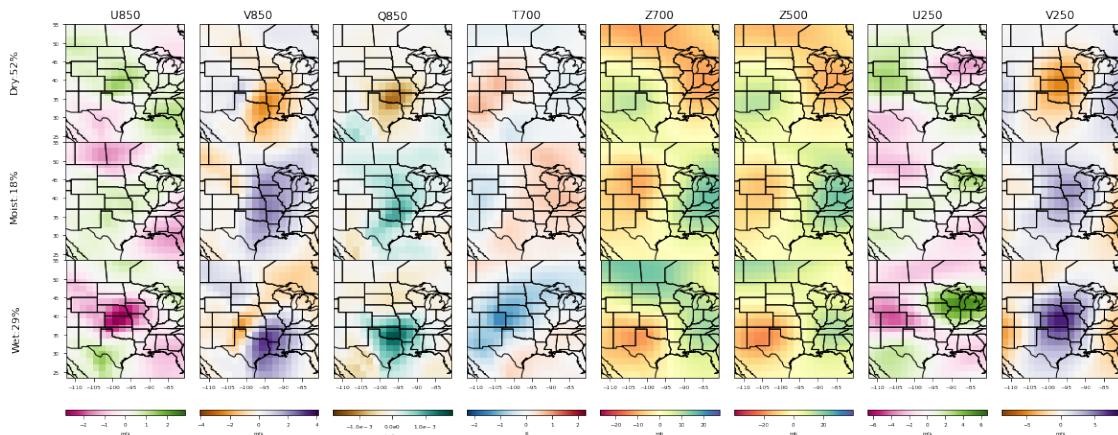
PREC HIST MPI-ESM-LR CNN



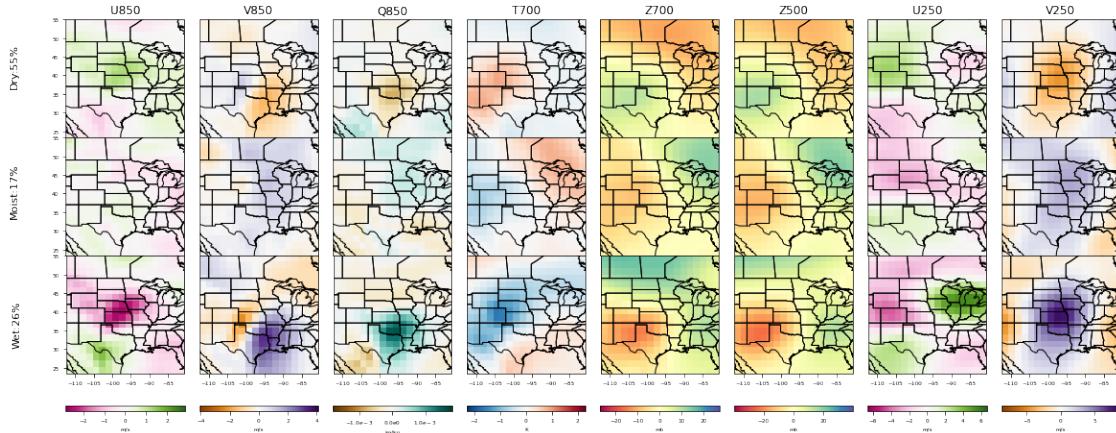
PREC HIST MPI-ESM-LR SDSM



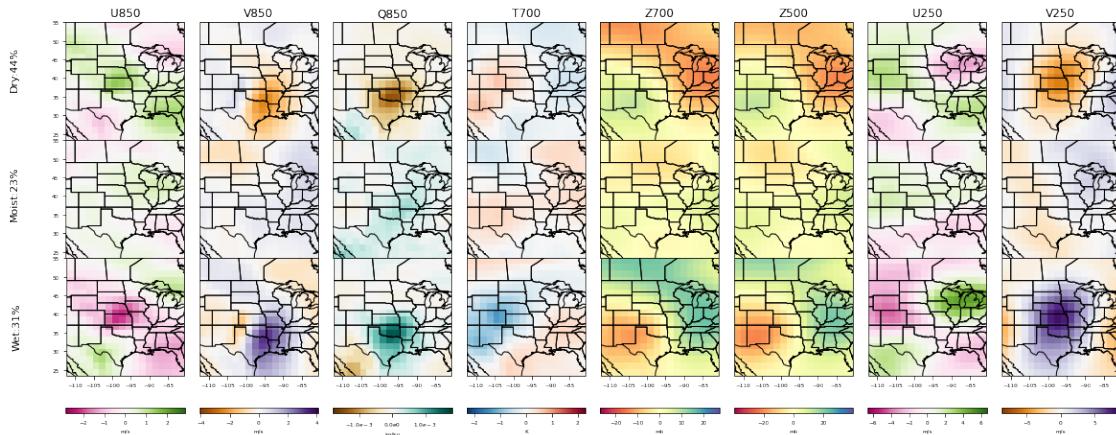
PREC HIST MPI-ESM-LR KDDM



PREC HIST MPI-ESM-LR MBCN



PREC HIST MPI-ESM-LR LOCA



## 6.0.2 RCP85

```
[28]: # find max/min for each variable accross ALL rcp85 files
#sigfiles_rcp85 = list(filter(lambda line: 'rcp85' in line, mpi_sigfiles))
sigfiles_rcp85 = [model2absfilepath(ff, 'rcp85', 98, 36) for ff in
                  ['raw', 'RegCM4', 'WRF', 'MPAS', 'CNN', 'SDSM', 'KDDM', 'MBCn', 'LOCA']]
```

```
# find min/max values for entire sigfiles set
vmin = 9999*np.ones(8)
vmax = -9999*np.ones(8)
for sigfile in sigfiles_rcp85:
```

```

# skip mpas in max/min range (it's too extreme)
if sigfile.lower().find('mpas') >= 0:
    continue
else:
    # load UATM and signal file
    if sigfile.lower().find('obs') >= 0:
        load_uatm_era()
    elif sigfile.lower().find('hist') >= 0:
        load_uatm_mpi_hist()
    elif sigfile.lower().find('rcp85') >= 0:
        load_uatm_mpi_future()
    else:
        print ("ERROR: neither hist or rcp85 found")
rainsignal = xr.open_dataset(sigfile)['prec']

for mpr_min, mpr_max in [(0,0.254), (0.254, 3.0), (3.0, 9999.0)]:
    avginput, count, distribution, indices = calc_uatm_average(mpr_min, mpr_max, rainsignal, -9999, 9999)

    # subtract clim
    if sigfile.lower().find('obs') >= 0:
        avginput-=era_allinput # era
    else:
        avginput-=allinput # mpi

    vmin = [min(avginput[ii].min(),vmin[ii]) for ii in range(8)]
    vmax = [max(avginput[ii].max(),vmax[ii]) for ii in range(8)]

```

[29]:

```
print(vmin)
print(vmax)
```

```

[-3.452042793828715, -3.1080816655337546, -0.00043432675100598533,
1.5546422505573787, 16.262461221018384, 46.64347925192578, -8.009037714663739,
-9.351981041310896]
[2.9014430255464605, 5.050055650965736, 0.004705679472396845, 6.050240335068963,
76.0449612998309, 132.17535390264948, 9.083836709299396, 9.975071366995373]
```

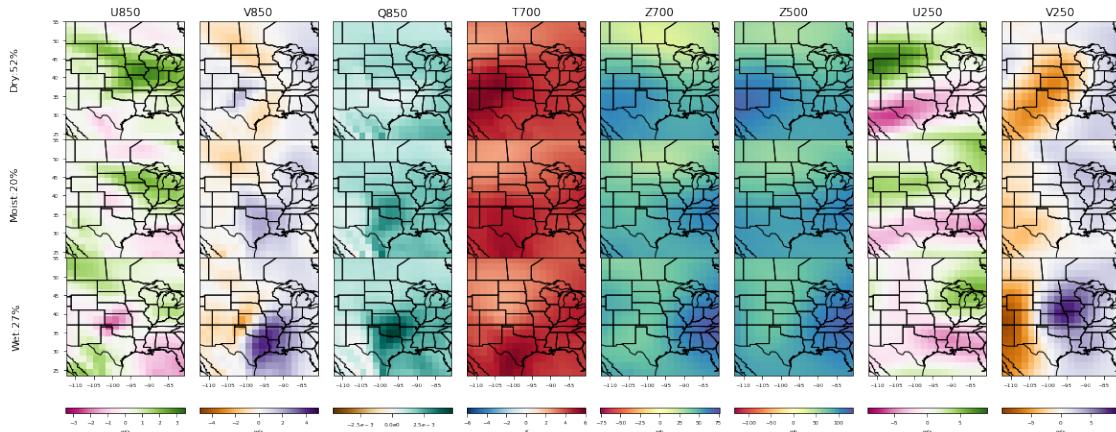
[30]:

```
# plot mpi dry/moist/wet: rcp85
print("RCP85")
#sigfiles_rcp85 = list(filter(lambda line:'rcp85' in line, mpi_sigfiles))
sigfiles_rcp85 = [model2absfilepath(ff, 'rcp85', 98, 36) for ff in [
    'raw', 'RegCM4', 'WRF', 'MPAS', 'CNN', 'SDSM', 'KDDM', 'MBCn', 'LOCA']]
```

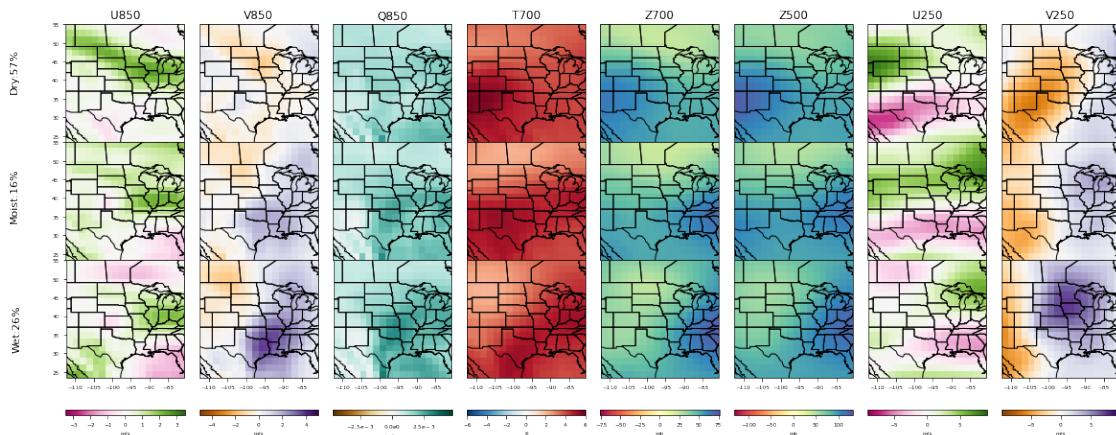
```
#plot_models(sigfiles_rcp85)
plot_models_group_drymoistwet(sigfiles_rcp85, vmin, vmax)
```

RCP85

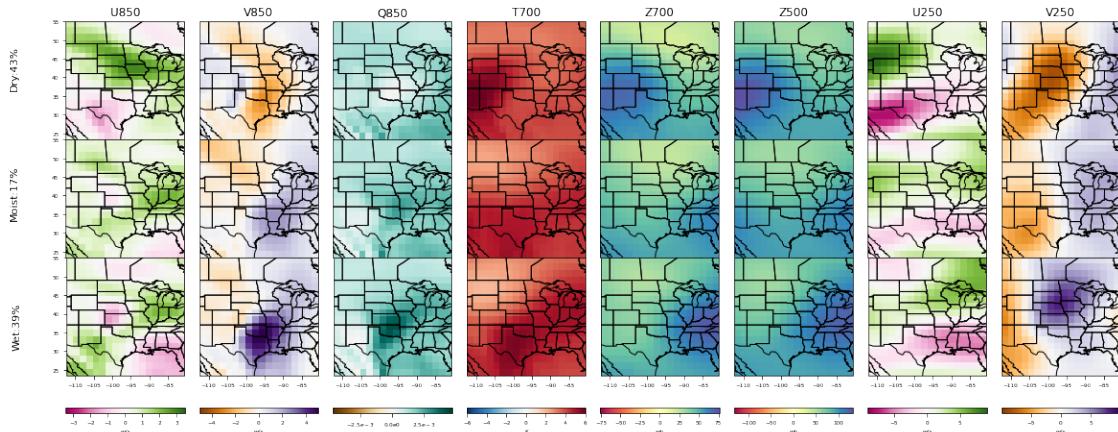
PREC RCP85 MPI-ESM-LR RAW



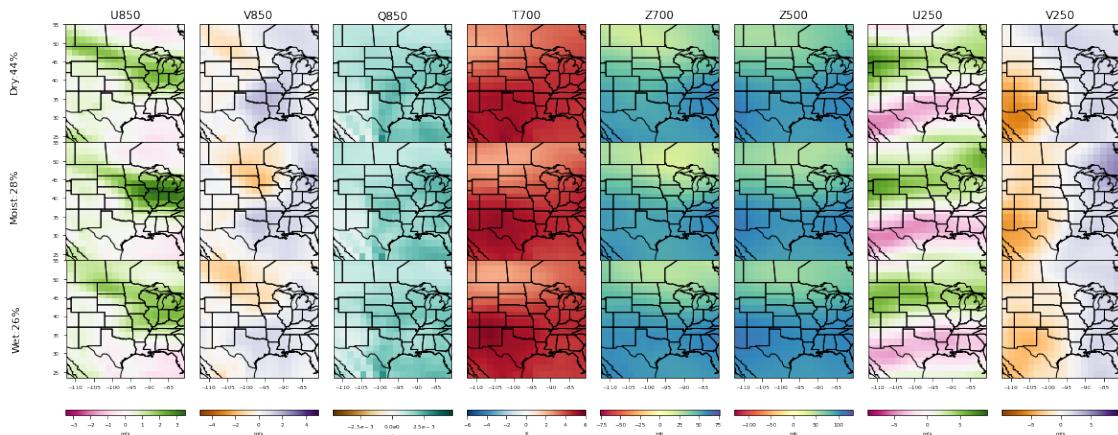
PREC RCP85 MPI-ESM-LR REGCM4



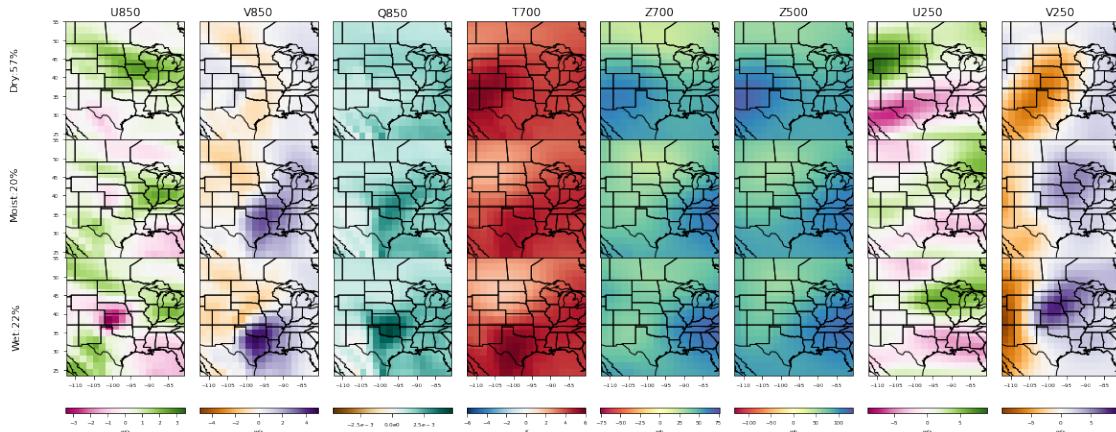
PREC RCP85 MPI-ESM-LR WRF



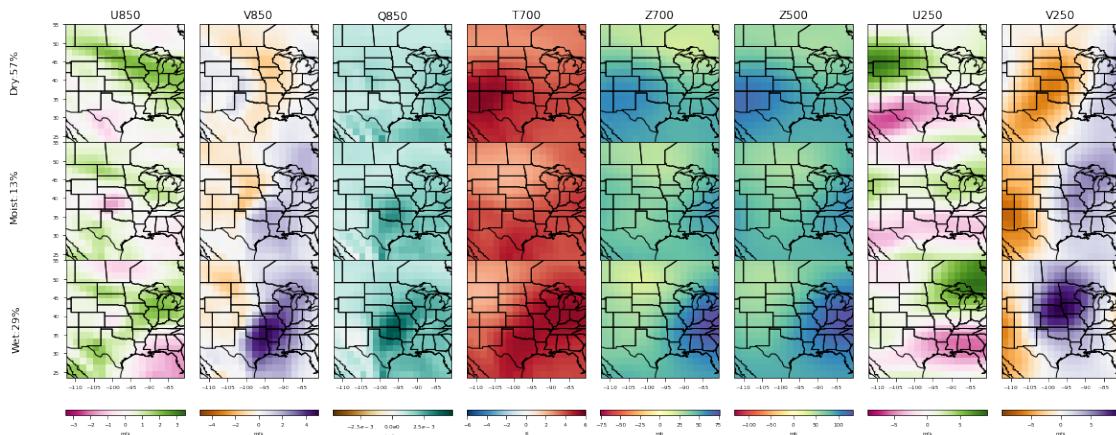
PREC RCP85 MPI-ESM-LR MPAS



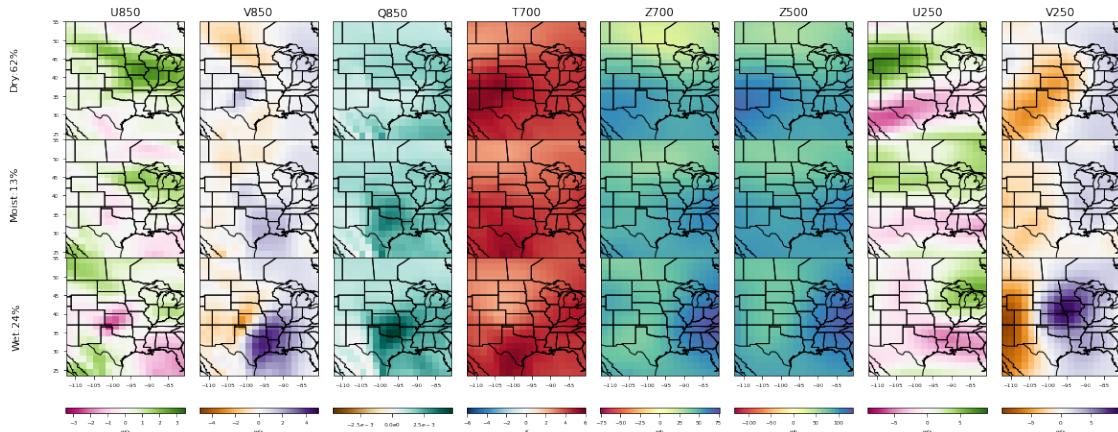
PREC RCP85 MPI-ESM-LR CNN



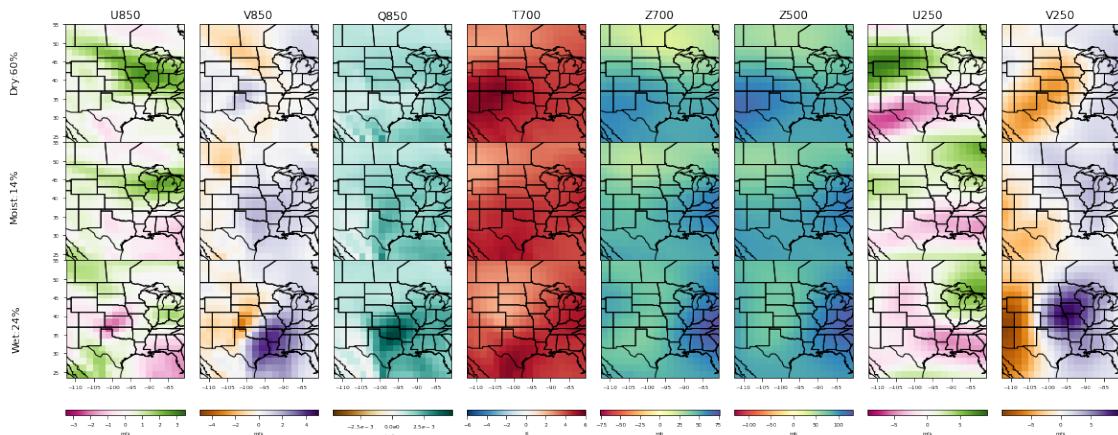
PREC RCP85 MPI-ESM-LR SDSM



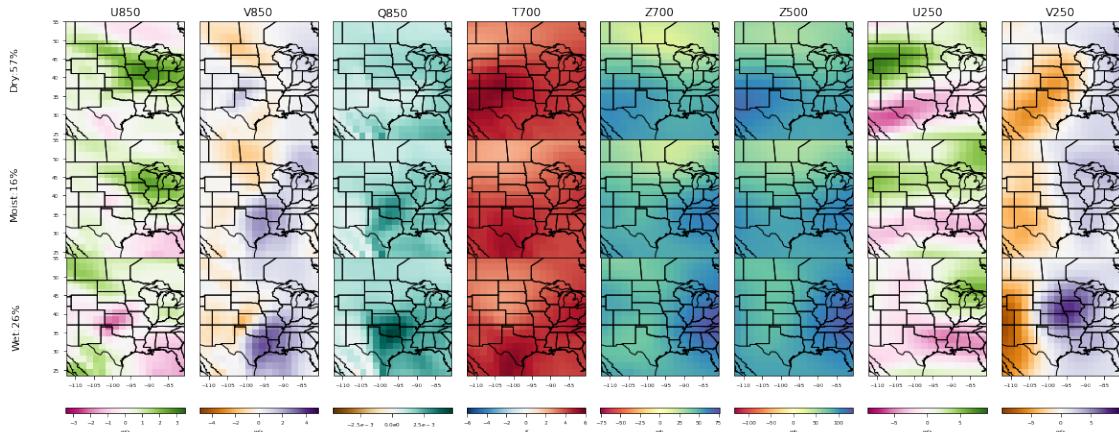
PREC RCP85 MPI-ESM-LR KDDM



PREC RCP85 MPI-ESM-LR MBCN



PREC RCP85 MPI-ESM-LR LOCA



[31]: 2

[31]: 2

[ ]: