elevation-analysis

January 10, 2025

[1]:
```
import os
import glob

import numpy as np
import pandas as pd
import xarray as xr
import netCDF4

import matplotlib.pyplot as plt
from   matplotlib.lines import Line2D
```

1 Evaluate Grid Cell Elevation

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Date: 01/01/25

Description:
Analysis of the actual elevation of each site vs. the grid cell elevation for each site.

Elevations were extracted from a 1m resolution DEM of Santa Cruz Island for each site.

Sites:
- Sauces: 34° 0'3.72"N, 119°49'4.14"W (LAT: 34.001033, LONG: -119.817817) - UPEM: 34° 0'45.11"N, 119°48'6.58"W (LAT: 34.012531, LONG: -119.801828) - NRS SCI: LAT: 33.995943, LONG: -119.716437

Note: This script was designed to run on the server that hosts the WRF output data.

2 Functions

[ ]:
```
def get_elev(site_dict, terrain):
    """
    Extract the elevation of the site coordinates from the terrain raster.␣
 ↪Prints the elevation that's represented in WRF.

    Parameters
    ----------
    site_dict : dict
```

```
        Dictionary of site attributes - including latitude, longitude, and site␣
↪name.
    terrain : xarray.Dataset
        A raster representing the terrain of central california, including␣
↪Santa Cruz Island.

    Returns
    -------
    np.series
        A series where each observation is the distance of that cell grid␣
↪center to the site coordinates. Used in interp_elevations
        to find the points that we interpolated from.

    """
    xlat = site_dict['xlat']
    xlon = site_dict['xlon']
    site = site_dict['name']

    slat = terrain['XLAT'].values
    slon = terrain['XLONG'].values
    dist = np.sqrt((slat - xlat)**2 + (slon - xlon)**2)
    ind  = np.unravel_index(np.argmin(dist, axis=None), dist.shape)
    elev = terrain[ind[0],ind[1]].values

    print(f"{site}: {elev}m")
    return dist

def interp_elevations(terrain, dist, site_dict):
    """
    Find the four grid cell centers closest to the point. These are the points␣
↪that we use to interpolate the extracted WRF
    data to the site coordinates.

    Parameters
    ----------
    terrain : xarray.Dataset
        A raster representing the terrain of central california, including␣
↪Santa Cruz Island.
    dist : np.series
        A series where each observation is the distance of that grid cell␣
↪center to the site coordinates.
    site_dict : dict
        Dictionary of site attributes - including latitude, longitude, and site␣
↪name.
    """
    # Assign labels to coords
```

```
    ds = terrain
    lats = ds['XLAT'].values[:,0]
    lons = ds['XLONG'][0]

    ds = ds.assign_coords({'south_north':('south_north', lats)})
    ds = ds.assign_coords({'west_east':('west_east', lons)})

    # Find 4 nearest points to target
    flat_indices = np.argsort(dist.ravel())[:3]
    indices = np.unravel_index(flat_indices, dist.shape)

    # Get bounding box to crop dataset
    near_lats = ds['XLAT'].values[indices[0], indices[1]]
    near_lons = ds['XLONG'].values[indices[0], indices[1]]

    max_lat = np.max(near_lats)
    min_lat = np.min(near_lats)
    max_lon = np.max(near_lons)
    min_lon = np.min(near_lons)

    # Crop dataset to locality of target
    ds_local = ds.sel(south_north=slice(min_lat,max_lat),␣
 ↪west_east=slice(min_lon,max_lon))

    print(site_dict['name'])
    results = []
    for i in [0, 1]:
        for j in [0, 1]:
            elev = round(float(ds_local[i][j].values), 2)
            lat = round(float(ds_local[i][j]['XLAT'].values), 4)
            lon = round(float(ds_local[i][j]['XLONG'].values), 4)
            print(f"{lat}, {lon}: {elev}m")
            results.append([lat, lon, elev])

    df = pd.DataFrame(results, columns=['latitude', 'longitude', 'elevation'])
    print("\n")

    return df

def plot_transect(coords, grid_elev, true_elev, xlab, title):
    """
    Plots the elevation transect of the observational data and WRF data for␣
 ↪comparison.

    Parameters
    ----------
    coords : list of float
```

```
        Transect coordinates, including the station coordinates and the␣
↪coordinates of the nearest grid cell centers - either latitudinally
        or longitudinally.
    grid_elev : list of float
        WRF elevations associated with each point of the transect.
    true_elev : list of float
        Observational elevations associated with each point of the transect -␣
↪extract from a DEM developed using aerial LiDAR.
    title : str
        Title of the plot

    Returns
    -------
    None

    """
    diff = coords[0] - coords[2]
    ind = [(x - coords[2])/diff for x in coords]

    fig, ax = plt.subplots()
    ax.plot(ind, grid_elev, color='blue', label='Grid Cell Elevations')
    ax.plot(ind, true_elev, color='orange', label='True Elevations')
    ax.scatter(ind, grid_elev, color='blue')
    ax.scatter(ind, true_elev, color='orange')

    ax.set_xlim(1, 0)
    ax.axvline(x=ind[1], color='black', linestyle='--', alpha=0.5)
    ax.text(ind[1], ax.get_ylim()[0] - 14, 'Station Location', color='black',␣
↪ha='center')
    ax.text(ind[0], ax.get_ylim()[0] - 6, coords[0], color='black', ha='center')
    ax.text(ind[2], ax.get_ylim()[0] - 6, coords[2], color='black', ha='center')

    ax.set_xticks([])
    ax.set_xlabel(xlab)
    ax.legend()

    ax.set_title(title)
    plt.show()
```

3 Prepare Data

3.1 Prepare Terrain

This is the dataset from which we'll extract the WRF elevations.

[2]:
```
#  Open geogrid file
file     = '/home/sbarc/wrf/wrf401/sbareg/geo_em.d04.nc'
```

```
ds       = xr.open_dataset(file)
ds

#   read one 2DVar file to get coordinates
path     = '/home/sbarc/wrf/wrf401/sbareg/'
yr1      = 1988
m        = 0
files    = sorted(glob.glob(path + str(yr1+m) + '/wrfout_d04_2DVar_*.nc'))
f2       = xr.open_dataset(files[m])

#   creat xarray
terrain  = xr.DataArray(ds['HGT_M'][0,:,:].values, dims␣
 ↪=("south_north","west_east"), name="terrain",
                   coords={"XLAT":f2['XLAT'],"XLONG":f2['XLONG']},
                   attrs ={'terrain':'elevation (m)'})
```

[3]:
```
f2
```

[3]:
```
<xarray.Dataset>
Dimensions:   (Time: 24, bottom_top: 54, south_north: 234, west_east: 258)
Coordinates:
    XLAT      (south_north, west_east) float32 …
    XLONG     (south_north, west_east) float32 …
Dimensions without coordinates: Time, bottom_top, south_north, west_east
Data variables:
    HGT       (south_north, west_east) float32 …
    Times     (Time) |S19 …
    Q2        (Time, south_north, west_east) float32 …
    T2        (Time, south_north, west_east) float32 …
    TH2       (Time, south_north, west_east) float32 …
    PSFC      (Time, south_north, west_east) float32 …
    U10       (Time, south_north, west_east) float32 …
    V10       (Time, south_north, west_east) float32 …
    FGDP      (Time, south_north, west_east) float32 …
    DFGDP     (Time, south_north, west_east) float32 …
    VDFG      (Time, south_north, west_east) float32 …
    RAINNC    (Time, south_north, west_east) float32 …
    I_RAINNC  (Time, south_north, west_east) int32 …
    CLDFRA    (Time, bottom_top, south_north, west_east) float32 …
    LWUPB     (Time, south_north, west_east) float32 …
    LWDNB     (Time, south_north, west_east) float32 …
    SWUPB     (Time, south_north, west_east) float32 …
    SWDNB     (Time, south_north, west_east) float32 …
    UST       (Time, south_north, west_east) float32 …
    HFX       (Time, south_north, west_east) float32 …
    QFX       (Time, south_north, west_east) float32 …
    LH        (Time, south_north, west_east) float32 …
```

```
    GRDFLX    (Time, south_north, west_east) float32 …
    PBLH      (Time, south_north, west_east) float32 …
Attributes:
    TITLE:                              OUTPUT FROM WRF V4.0.1 MODEL
    START_DATE:                         1987-07-01_00:00:00
    SIMULATION_START_DATE:              1987-07-01_00:00:00
    WEST-EAST_GRID_DIMENSION:           259
    SOUTH-NORTH_GRID_DIMENSION:         235
    BOTTOM-TOP_GRID_DIMENSION:          55
    DX:                                 1000.0
    DY:                                 1000.0
    AERCU_OPT:                          0
    AERCU_FCT:                          1.0
    IDEAL_CASE:                         0
    DIFF_6TH_SLOPEOPT:                  0
    AUTO_LEVELS_OPT:                    2
    DIFF_6TH_THRESH:                    0.1
    DZBOT:                              50.0
    DZSTRETCH_S:                        1.3
    DZSTRETCH_U:                        1.1
    SKEBS_ON:                           0
    SPEC_BDY_FINAL_MU:                  1
    USE_Q_DIABATIC:                     0
    GRIDTYPE:                           C
    DIFF_OPT:                           2
    KM_OPT:                             4
    DAMP_OPT:                           3
    DAMPCOEF:                           0.2
    KHDIF:                              0.0
    KVDIF:                              0.0
    MP_PHYSICS:                         6
    RA_LW_PHYSICS:                      4
    RA_SW_PHYSICS:                      4
    SF_SFCLAY_PHYSICS:                  5
    SF_SURFACE_PHYSICS:                 4
    BL_PBL_PHYSICS:                     5
    CU_PHYSICS:                         0
    SF_LAKE_PHYSICS:                    0
    SURFACE_INPUT_SOURCE:               1
    SST_UPDATE:                         1
    GRID_FDDA:                          0
    GFDDA_INTERVAL_M:                   0
    GFDDA_END_H:                        0
    GRID_SFDDA:                         0
    SGFDDA_INTERVAL_M:                  0
    SGFDDA_END_H:                       0
    HYPSOMETRIC_OPT:                    2
```

```
USE_THETA_M:                    1
GWD_OPT:                        0
SF_URBAN_PHYSICS:               0
SF_SURFACE_MOSAIC:              0
SF_OCEAN_PHYSICS:               0
SHCU_PHYSICS:                   0
MFSHCONV:                       0
FEEDBACK:                       1
SMOOTH_OPTION:                  0
SWRAD_SCAT:                     1.0
W_DAMPING:                      0
DT:                             3.3333333
RADT:                           10.0
BLDT:                           0.0
CUDT:                           0.0
AER_OPT:                        0
SWINT_OPT:                      0
AER_TYPE:                       1
AER_AOD550_OPT:                 1
AER_ANGEXP_OPT:                 1
AER_SSA_OPT:                    1
AER_ASY_OPT:                    1
AER_AOD550_VAL:                 0.12
AER_ANGEXP_VAL:                 1.3
AER_SSA_VAL:                    0.85
AER_ASY_VAL:                    0.9
MOIST_ADV_OPT:                  1
SCALAR_ADV_OPT:                 1
TKE_ADV_OPT:                    1
DIFF_6TH_OPT:                   0
DIFF_6TH_FACTOR:                0.12
OBS_NUDGE_OPT:                  0
BUCKET_MM:                      100.0
BUCKET_J:                       1000000000.0
PREC_ACC_DT:                    0.0
ISFTCFLX:                       0
ISHALLOW:                       0
ISFFLX:                         1
ICLOUD:                         1
ICLOUD_CU:                      0
TRACER_PBLMIX:                  1
SCALAR_PBLMIX:                  0
YSU_TOPDOWN_PBLMIX:             0
GRAV_SETTLING:                  2
OPT_SFC:                        1
DVEG:                           4
OPT_CRS:                        1
```

```
OPT_BTR:                            1
OPT_RUN:                            1
OPT_FRZ:                            1
OPT_INF:                            1
OPT_RAD:                            3
OPT_ALB:                            2
OPT_SNF:                            1
OPT_TBOT:                           2
OPT_STC:                            1
OPT_GLA:                            1
OPT_RSF:                            1
OPT_SOIL:                           1
OPT_PEDO:                           1
OPT_CROP:                           0
DFI_OPT:                            0
SIMULATION_INITIALIZATION_TYPE:     REAL-DATA CASE
WEST-EAST_PATCH_START_UNSTAG:       1
WEST-EAST_PATCH_END_UNSTAG:         258
WEST-EAST_PATCH_START_STAG:         1
WEST-EAST_PATCH_END_STAG:           259
SOUTH-NORTH_PATCH_START_UNSTAG:     1
SOUTH-NORTH_PATCH_END_UNSTAG:       234
SOUTH-NORTH_PATCH_START_STAG:       1
SOUTH-NORTH_PATCH_END_STAG:         235
BOTTOM-TOP_PATCH_START_UNSTAG:      1
BOTTOM-TOP_PATCH_END_UNSTAG:        54
BOTTOM-TOP_PATCH_START_STAG:        1
BOTTOM-TOP_PATCH_END_STAG:          55
GRID_ID:                            4
PARENT_ID:                          3
I_PARENT_START:                     68
J_PARENT_START:                     64
PARENT_GRID_RATIO:                  3
CEN_LAT:                            34.51162
CEN_LON:                            -119.91917
TRUELAT1:                           30.0
TRUELAT2:                           60.0
MOAD_CEN_LAT:                       35.999992
STAND_LON:                          0.0
POLE_LAT:                           90.0
POLE_LON:                           0.0
GMT:                                0.0
JULYR:                              1987
JULDAY:                             182
MAP_PROJ:                           3
MAP_PROJ_CHAR:                      Mercator
MMINLU:                             MODIFIED_IGBP_MODIS_NOAH
```

```
NUM_LAND_CAT:                   21
ISWATER:                        17
ISLAKE:                         21
ISICE:                          15
ISURBAN:                        13
ISOILWATER:                     14
HYBRID_OPT:                     0
ETAC:                           0.0
```

3.2 Select Domain to Crop

Crop WRF data to SCI

[4]:
```
#### Define geographic domain ####
i1 = 20
i2 = 135
j1 = 50
j2 = 199
```

[5]:
```
#### Crop terrain and landmask ####
terrain  = terrain[i1:i2+1,j1:j2+1]
```

[5]:
```
(116, 150)
```

4 Extract Elevations

4.1 Define sites

[7]:
```
sauc_site_dict = {
    'name' : 'sauc',
    'xlat' : 34.001033,
    'xlon' : -119.817817
}

upem_site_dict = {
    'name' : 'upem',
    'xlat' : 34.012531,
    'xlon' : -119.801828
}

nrs_site_dict = {
    'name' : 'nrs_sci',
    'xlat' : 33.995943,
    'xlon' : -119.716437
}
```

4.2 Get Elevations

Extract elevations from the WRF dataset, then get the WRF elevations of the points that will be used to interpolate.

[10]:
```
sauc_dist = get_elev(sauc_site_dict)
upem_dist = get_elev(upem_site_dict)
nrs_dist = get_elev(nrs_site_dict)
```

```
sauc: 266.1056213378906m
upem: 327.22607421875m
nrs_sci: 156.2794189453125m
```

[12]:
```
df = interp_elevations(terrain, sauc_dist, sauc_site_dict)
df
#interp_elevations(terrain, upem_dist, upem_site_dict)
#interp_elevations(terrain, nrs_dist, nrs_site_dict)
```

```
sauc
34.0008, -119.8205: 266.11m
34.0008, -119.8101: 244.33m
34.0095, -119.8205: 269.14m
34.0095, -119.8101: 299.51m
```

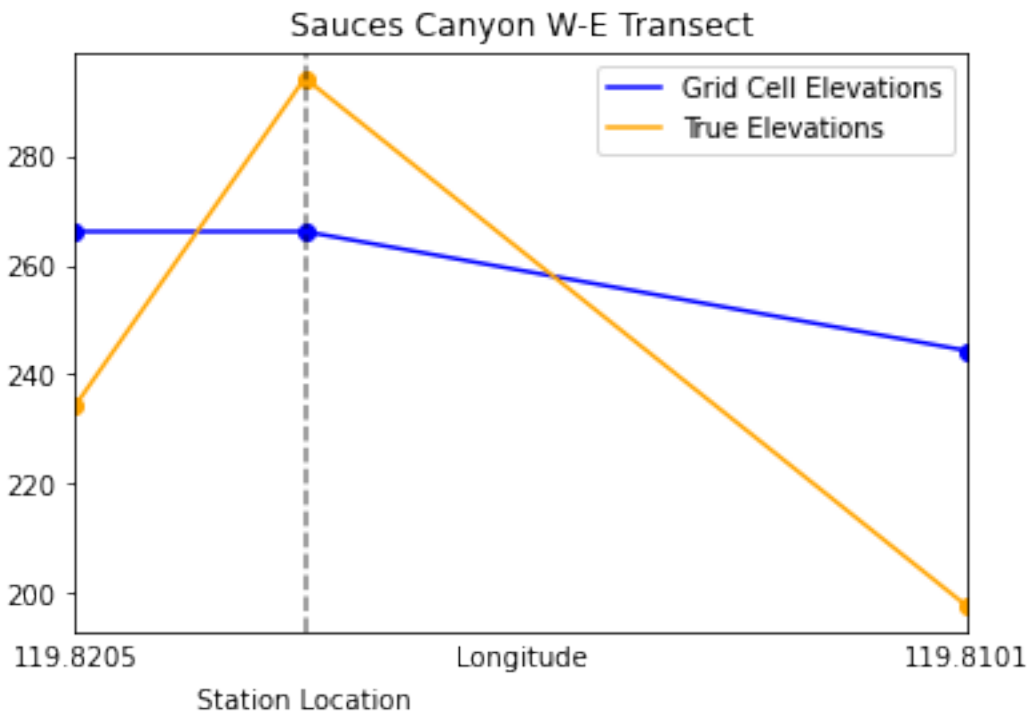
[12]:

	latitude	longitude	elevation
0	34.0008	-119.8205	266.11
1	34.0008	-119.8101	244.33
2	34.0095	-119.8205	269.14
3	34.0095	-119.8101	299.51

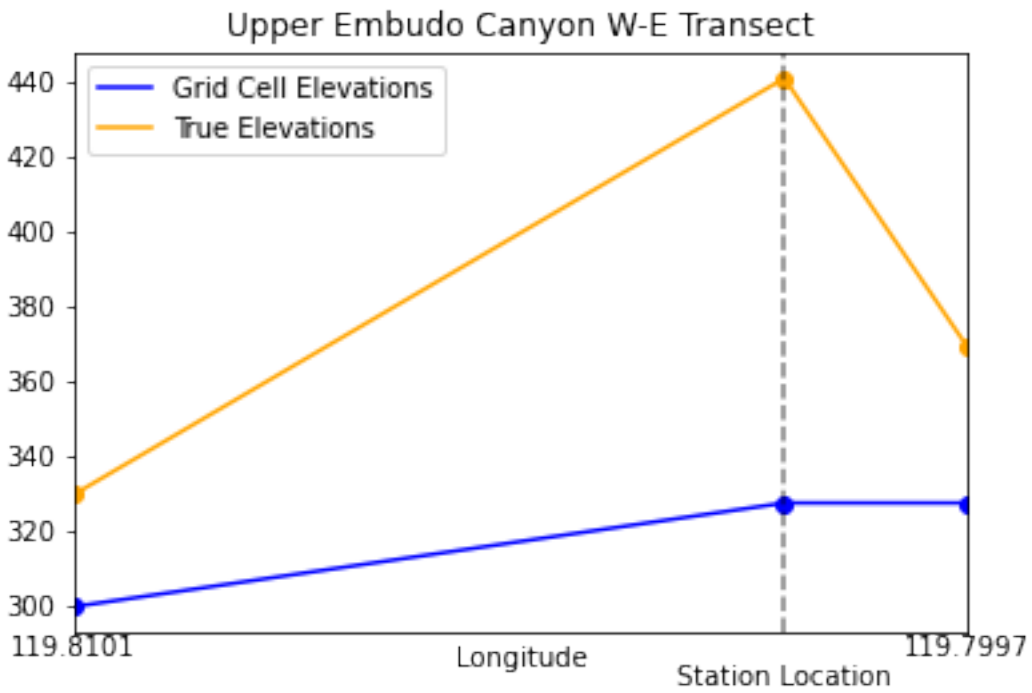
5 Visualize elevation profiles

Plot the actual elevation profiles of the site against the WRF profiles.

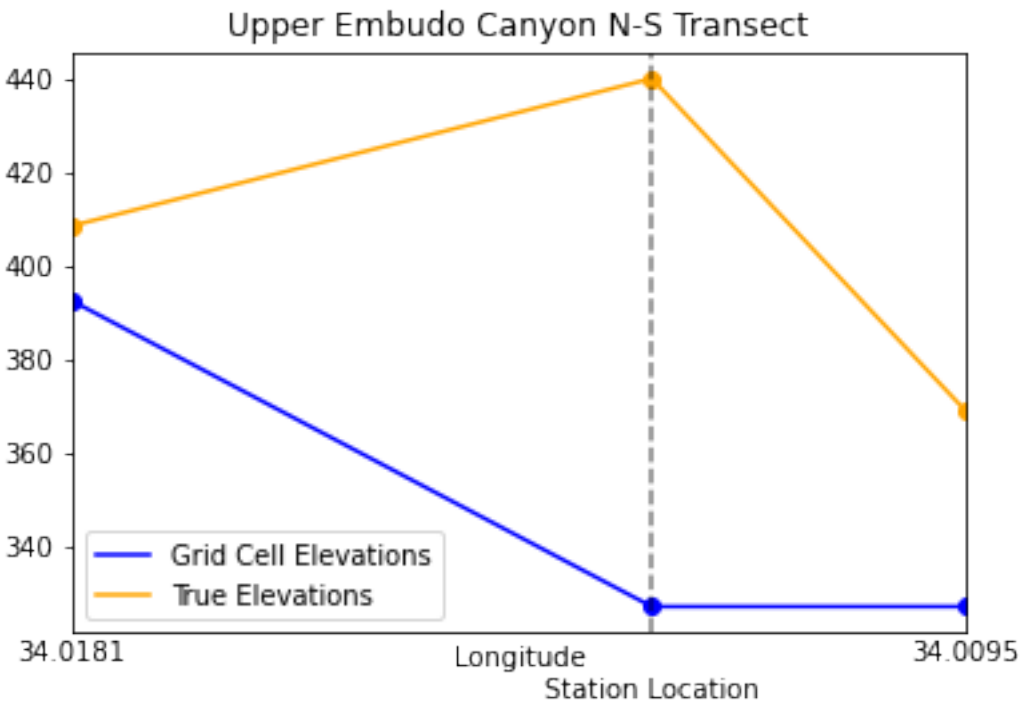
[13]:
```
title = "Sauces Canyon W-E Transect"
lons = [119.8205, 119.817817, 119.8101]
grid_elev = [266.11, 266.11, 244.33]
true_elev = [234.12, 294.15, 197.61]
plot_transect(lons, grid_elev, true_elev, 'Longitude', title)
```



[14]:
```
title = "Upper Embudo Canyon W-E Transect"
lons = [119.8101, 119.801828, 119.7997]
grid_elev = [299.51, 327.23, 327.23]
true_elev = [329.53, 440.78, 369.12]
plot_transect(lons, grid_elev, true_elev, 'Longitude', title)
```



[15]:
```
title = "Upper Embudo Canyon N-S Transect"
lats = [34.0181, 34.012521, 34.0095]
grid_elev = [392.63, 327.23, 327.23]
true_elev = [408.72, 440.23, 369.12]
plot_transect(lats, grid_elev, true_elev, 'Longitude', title)
```


Upper Embudo Canyon N-S Transect
440
420
400
380
360
340
Grid Cell Elevations
True Elevations
34.0181
Longitude
34.0095
Station Location