

process_4k_atterbury_survey

January 3, 2023

```
[ ]: from os import getcwd
from os.path import dirname, join

import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import numpy as np
import pandas as pd
import scipy.linalg as la
from matplotlib import cm

from MAMMAL import Diurnal
from MAMMAL.MapLvl import pcaLvl
from MAMMAL.MapLvl import tieLvl
from MAMMAL.Parse import parseGSMP as pgsmp
from MAMMAL.Parse import parseIM as pim
from MAMMAL.Parse import parseLCM as plcm
from MAMMAL.Utils import coordinateUtils as cu
from MAMMAL.Utils import Filters as filt
from MAMMAL.Utils import mapUtils as mu
from MAMMAL.Utils import ProcessingUtils as pu
from MAMMAL.VehicleCal import magUtilsTL as magtl

%matplotlib inline
plt.rcParams["figure.figsize"] = (30, 15) # (w, h)
plt.style.use(['seaborn-poster', 'seaborn-white'])
pd.set_option('mode.chained_assignment', None)

shrink = 0.8
aspect = 20 * 0.7
xlims = [-86.028, -85.9927]
ylims = [39.3050, 39.35]
cmap = cm.coolwarm
s = 10
alpha = 0.85
```

```

GMAP_EXTENT = [-86.067298, -85.952393, 39.302228, 39.349337]

SURVEY_DIR = getcwd()
IN_DIR      = join(SURVEY_DIR, 'input_data')
GMAP_FNAME = join(IN_DIR, 'atterbury_large.jpg')
REF_FNAME  = join(IN_DIR, 'Ground_Reference.csv')
LOG_FNAME  = join(IN_DIR, '__4k_atterbury_survey__.csv')
OUT_DIR    = join(SURVEY_DIR, 'output_data')

SURVEY_NAME = '4km Atterbury Survey'

MAX_TERRAIN_MSL   = 230 # (m)
MAX_SURVEY_AGL    = 400 # (m)
MAX_SURVEY_CRUISE = 30  # (m/s)

MAX_EXPECTED_FREQ = MAX_SURVEY_CRUISE / MAX_SURVEY_AGL # (hz)

TL_C      = np.array([-1.86687725e+01,  1.33975396e+02, -1.80762945e+02,  1.
                     ↪69023832e-01,
                     -3.92262356e-03, -1.84382741e-03,  1.71830230e-01, -1.
                     ↪61173781e-04,
                     1.72575427e-01, -4.31927864e-04, -8.21512835e-05, -4.
                     ↪37609432e-05,
                     -1.06838978e-04, -1.22444017e-04, -2.76294434e-04, -8.
                     ↪51727772e-05,
                     3.16374022e-05, -2.77441572e-05])
TL_TERMS = magtl.DEFAULT_TL_TERMS
TL_COEFF_TYPES = ['Permanent', 'Induced', 'Eddy']

SCALAR_TYPE = 'Geometrics MFAM optically pumped caesium scalar magnetometer'
                     ↪with 2 sensor heads'
VECTOR_TYPE = 'TwinLeaf VMR anisotropic magnetoresistive vector magnetometer'

FINAL_FILT_CUT   = MAX_SURVEY_AGL
FINAL_FILT_ORDER = 6

DX = 10 # Map pixel width (m)
DY = 10 # Map pixel height (m)

POC = '''Autonomy and Navigation Technology Center
        Air Force Institute of Technology
        Graduate School of Engineering and Management
        2950 Hobson Way, Bldg 646, Rm 205
        Wright Patterson AFB, Ohio 45433

        Telephone: (937) 255-3636 Ext. 4671'''
```

```
PROCESS_APP = 'MAMMAL 0.0.1'
```

1 Load Survey Data

```
[ ]: img = mpimg.imread(GMAP_FNAME)

ref_df = pd.read_csv(REF_FNAME, parse_dates=['datetime'])

log_df      = pd.read_csv(LOG_FNAME, parse_dates=['datetime'])
datetimes   = log_df.datetime
timestamps  = np.array(log_df.epoch_sec)
sample_rate = 1.0 / np.diff(timestamps).mean()
```

2 Interpolate Reference Data

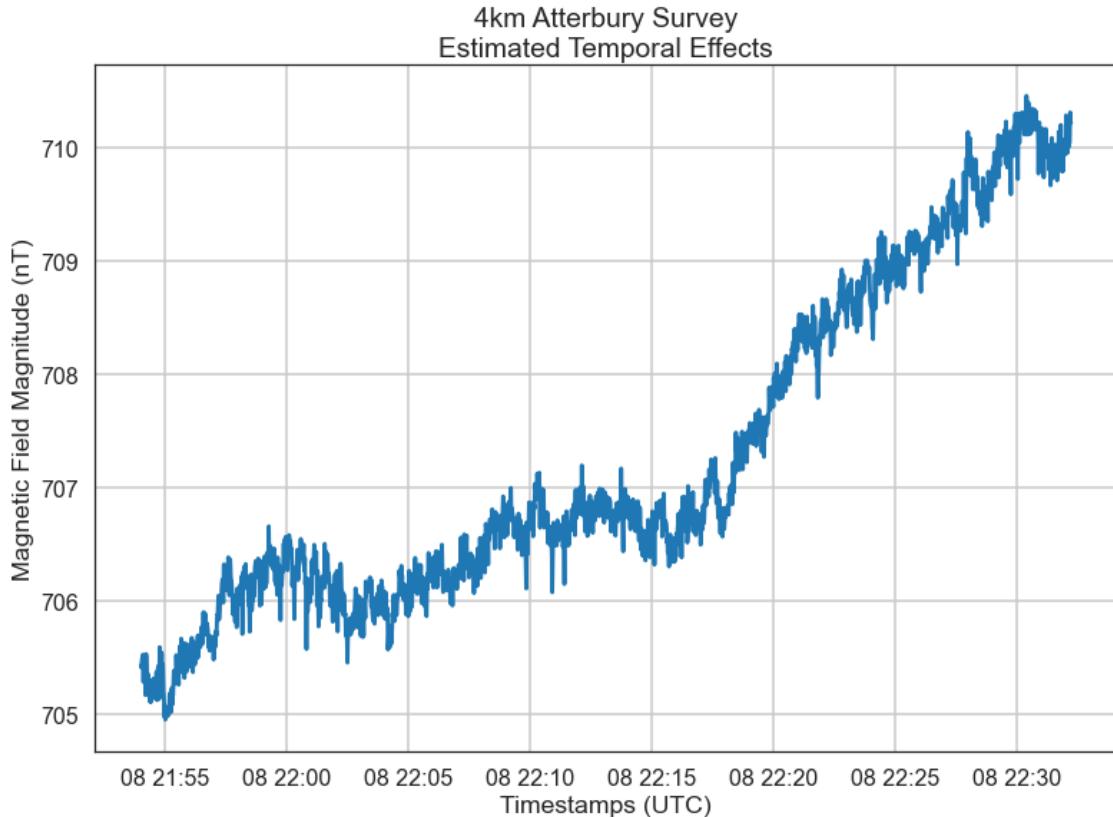
```
[ ]: # Despike reference data
span = 10
delta = 0.5

ref_despiked = pu.remove_outliers(ref_df.F, pu.ewma_fb(ref_df.F, span), delta)

ref_df.F = ref_despiked
ref_df.F = ref_df.F.interpolate()

# Interpolate reference data
_, ref_mag = Diurnal.interp_reference_df(df           = ref_df,
                                           timestamps = timestamps,
                                           survey_lon = log_df.LONG.mean(),
                                           subtract_core = True)

plt.figure()
plt.title('{}\\nEstimated Temporal Effects'.format(SURVEY_NAME))
plt.xlabel('Timestamps (UTC)')
plt.ylabel('Magnetic Field Magnitude (nT)')
plt.plot(log_df.datetime, ref_mag)
plt.grid()
```



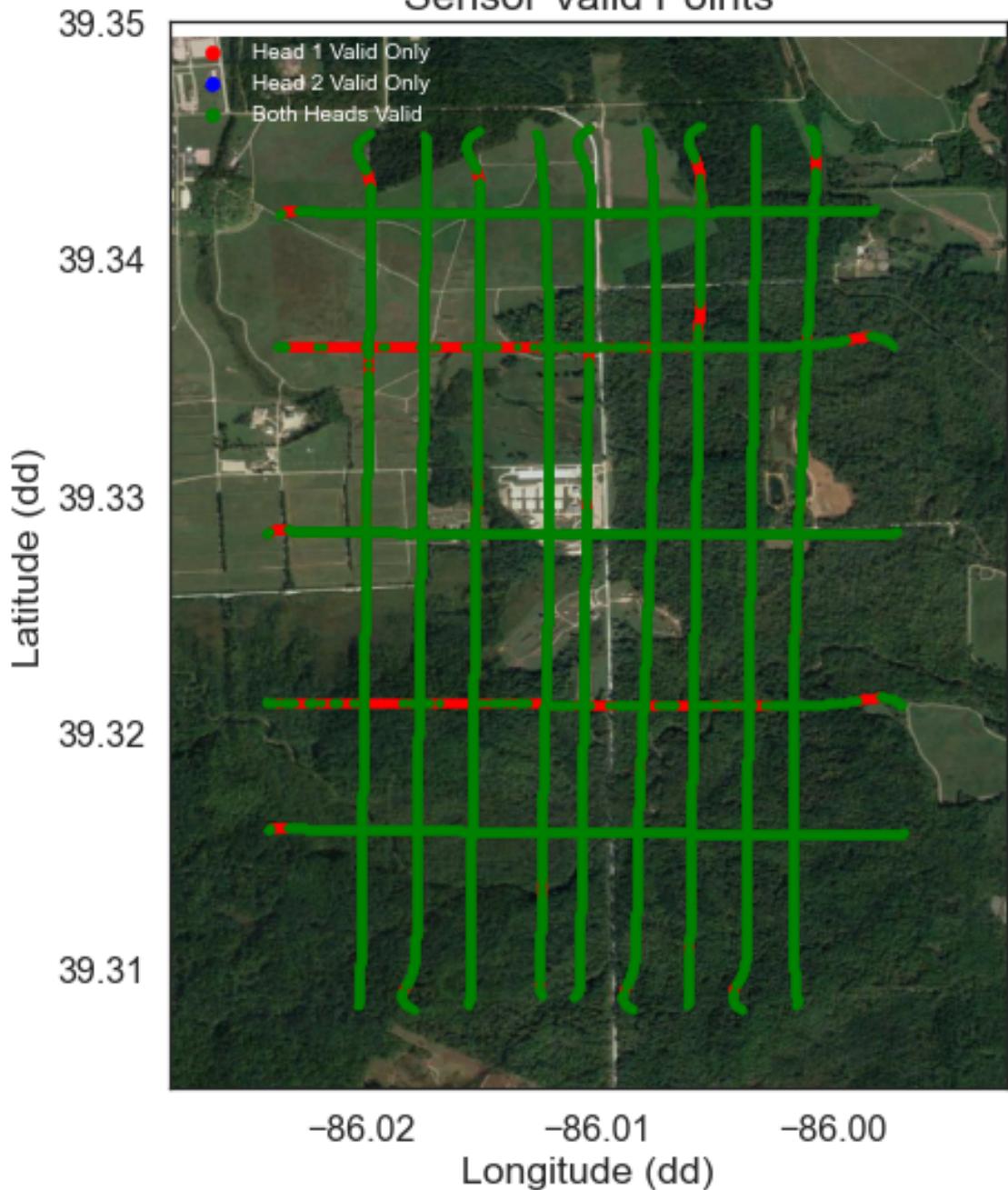
3 Determine When Each Sensor Head was Valid During the Survey

```
[ ]: plt.figure()
plt.title('{}\nSensor Valid Points'.format(SURVEY_NAME))
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
plt.scatter(log_df.LONG[(log_df.SCALAR_1_VALID == 1) & (log_df.SCALAR_2_VALID == 0) & (log_df.LINE_TYPE != 0)],
            log_df.LAT[(log_df.SCALAR_1_VALID == 1) & (log_df.SCALAR_2_VALID == 0) & (log_df.LINE_TYPE != 0)],
            s=s,
            c='r',
            label='Head 1 Valid Only')
plt.scatter(log_df.LONG[(log_df.SCALAR_1_VALID == 0) & (log_df.SCALAR_2_VALID == 1) & (log_df.LINE_TYPE != 0)],
            log_df.LAT[(log_df.SCALAR_1_VALID == 0) & (log_df.SCALAR_2_VALID == 1) & (log_df.LINE_TYPE != 0)],
```

```
s=s,
c='b',
label='Head 2 Valid Only')
plt.scatter(log_df.LONG[(log_df.SCALAR_1_VALID == 1) & (log_df.SCALAR_2_VALID == 1) & (log_df.LINE_TYPE != 0)],
            log_df.LAT[(log_df.SCALAR_1_VALID == 1) & (log_df.SCALAR_2_VALID == 1) & (log_df.LINE_TYPE != 0)],
            s=s,
            c='g',
            label='Both Heads Valid')
plt.legend(labelcolor='white', fontsize='medium', markerscale=2)
plt.xlim(xlims)
plt.ylim(ylims)
```

[]: (39.305, 39.35)

4km Atterbury Survey Sensor Valid Points



4 Apply Tolles Lawson Calibration

```
[ ]: # Compile vector data
b_vector = np.hstack([np.array(log_df.X)[:, np.newaxis],
                      np.array(log_df.Y)[:, np.newaxis],
                      np.array(log_df.Z)[:, np.newaxis]]))

dcs  = b_vector / la.norm(b_vector, axis=1)[:, np.newaxis]
dc_x = dcs[:, 0]
dc_y = dcs[:, 1]
dc_z = dcs[:, 2]

# Calibrate sensor head
f = (log_df.SCALAR_1_LPF + log_df.SCALAR_2_LPF) / 2.0

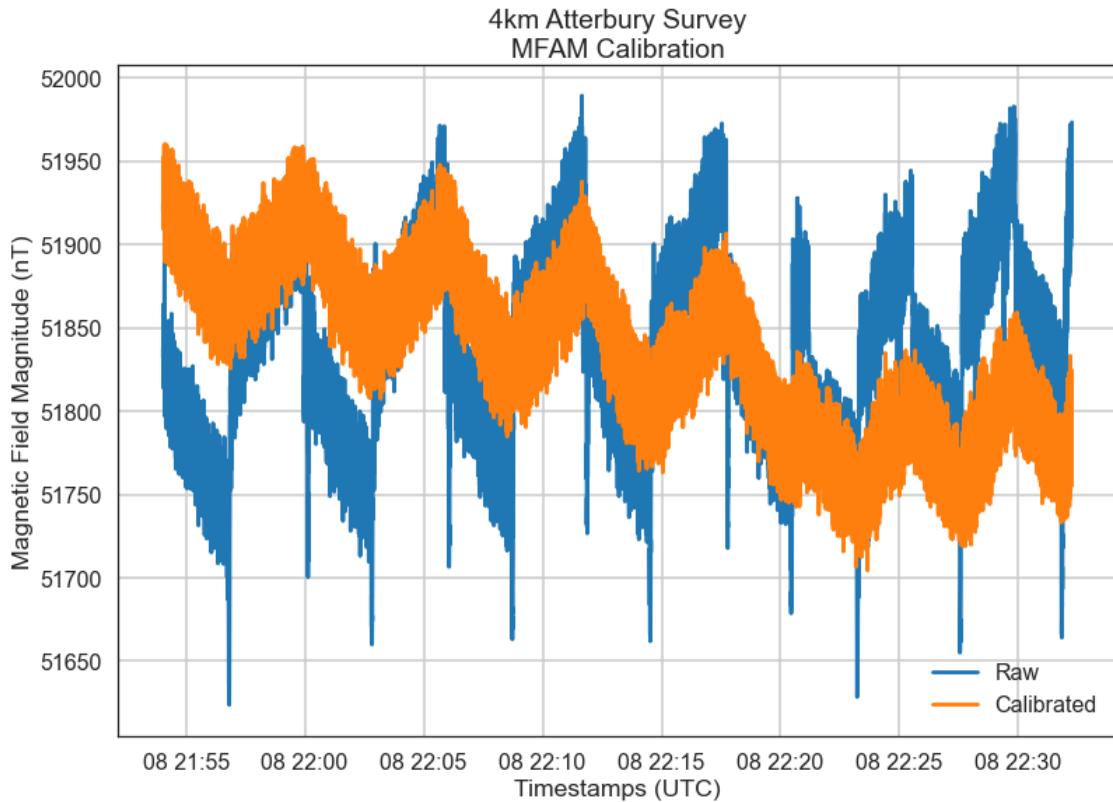
body_effects_scalar = magtl.tlc_compensation(vector = b_vector,
                                              tlc      = TL_C,
                                              terms   = TL_TERMS)

f_cal = f - body_effects_scalar

f_cal += (f.mean() - f_cal.mean())

# Update dataframe with calibrated data
log_df['SCALAR_CAL'] = f_cal
log_df['F']           = log_df.SCALAR_CAL

plt.figure()
plt.title('{}\nMFAM Calibration'.format(SURVEY_NAME))
plt.xlabel('Timestamps (UTC)')
plt.ylabel('Magnetic Field Magnitude (nT)')
plt.plot(log_df.datetime, f,      label='Raw')
plt.plot(log_df.datetime, f_cal, label='Calibrated')
plt.legend()
plt.grid()
```



5 Find Estimated Magnetic Anomaly Values

```
[ ]: f_cal_igrf = f_cal - log_df.IGRF_F
f_cal_igrf_temporal = f_cal_igrf - ref_mag
f_cal_igrf_temporal_filt = filt.lpf(f_cal_igrf_temporal, MAX_EXPECTED_FREQ,
                                     sample_rate)

process_dict = {'TIMESTAMP': timestamps,
                'LAT': log_df.LAT,
                'LONG': log_df.LONG,
                'ALT': log_df.ALT,
                'DC_X': dc_x,
                'DC_Y': dc_y,
                'DC_Z': dc_z,
                'F': f,
                'F_CAL': f_cal,
                'F_CAL_IGRF': f_cal_igrf,
                'F_CAL_IGRF_TEMPORAL': f_cal_igrf_temporal,
                'F_CAL_IGRF_TEMPORAL_FILTER': f_cal_igrf_temporal_filt}
```

```

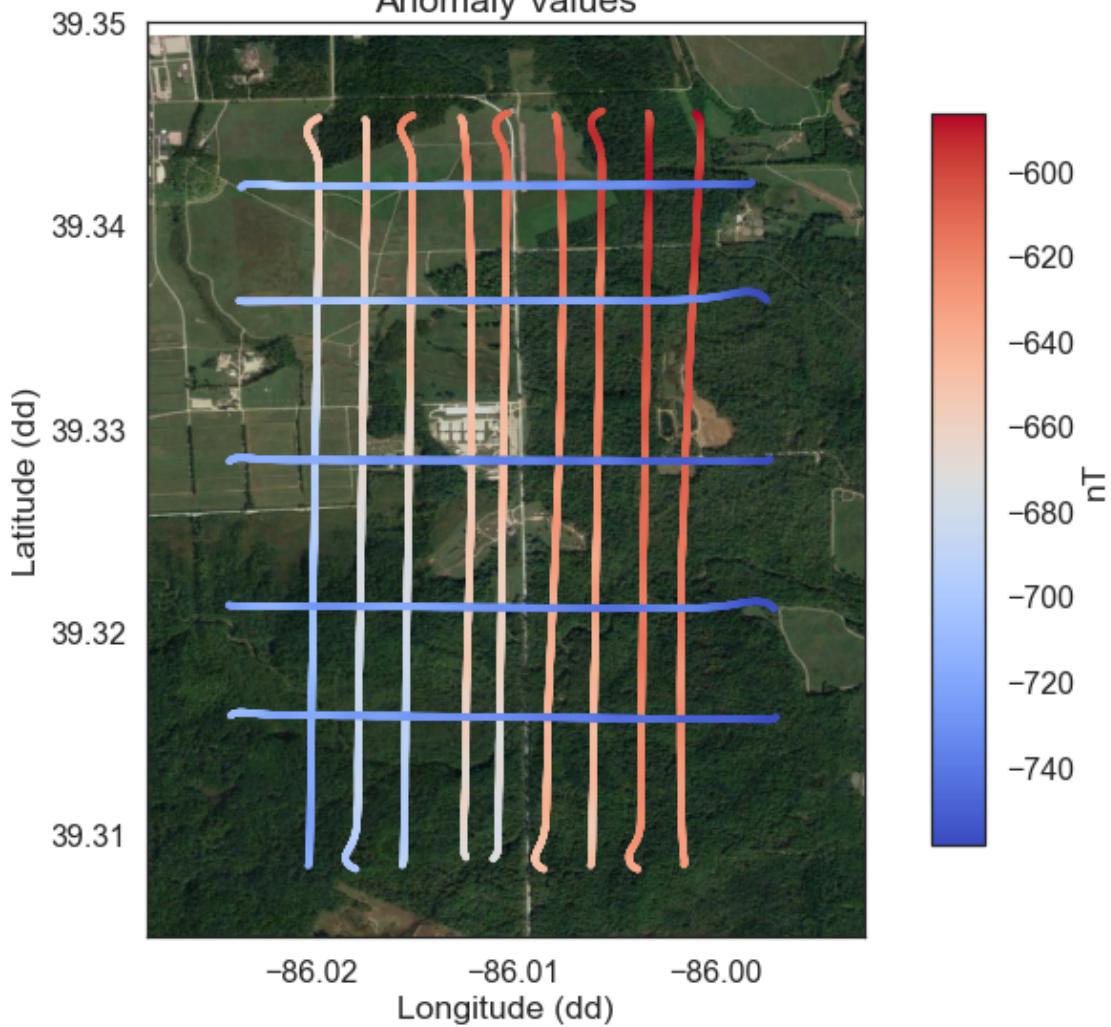
log_df.F = f_cal_igrf_temporal_filt

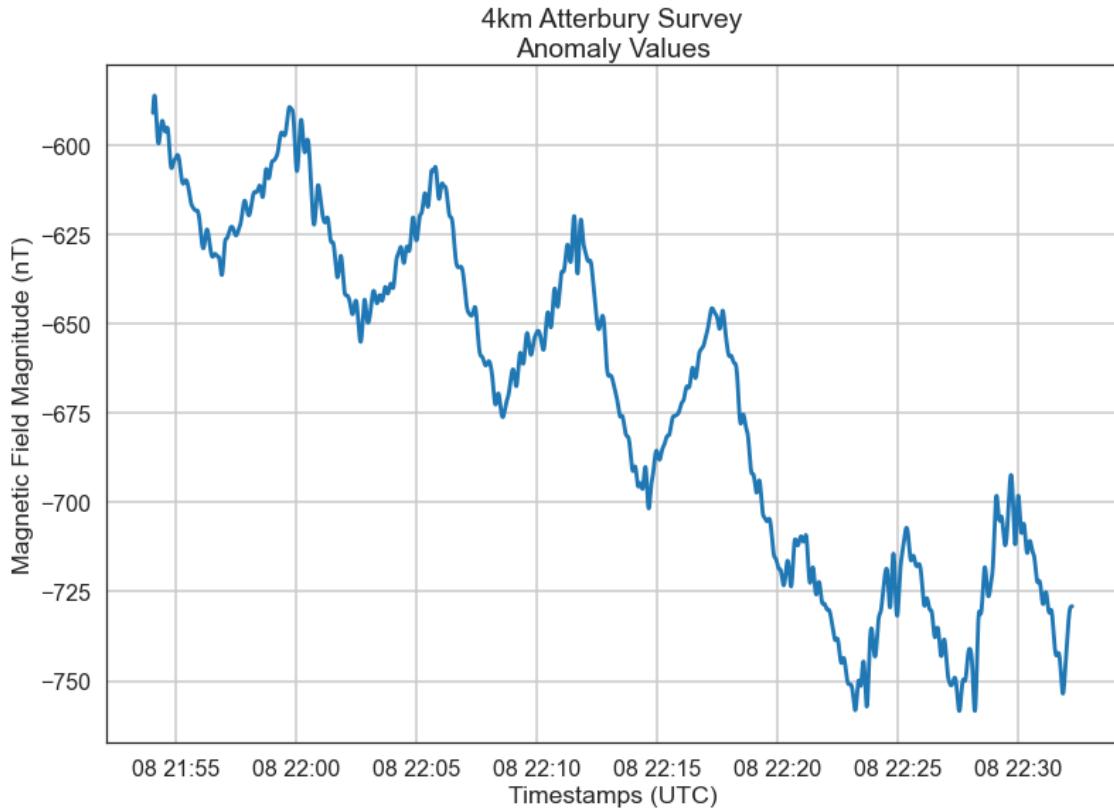
plt.figure()
plt.title('{}\\nAnomaly Values'.format(SURVEY_NAME))
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.scatter(log_df.LONG[log_df.LINE_TYPE != 0],
                  log_df.LAT[log_df.LINE_TYPE != 0],
                  s=s,
                  c=log_df.F[log_df.LINE_TYPE != 0],
                  cmap=cmap)
plt.xlim(xlims)
plt.ylim(ylims)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)

plt.figure()
plt.title('{}\\nAnomaly Values'.format(SURVEY_NAME))
plt.xlabel('Timestamps (UTC)')
plt.ylabel('Magnetic Field Magnitude (nT)')
plt.plot(log_df.datetime, log_df.F)
plt.grid()

```

4km Atterbury Survey Anomaly Values





6 Crop Map Extent

```
[ ]: MIN_MAP_LAT = 39.3127
      MAX_MAP_LAT = 39.3427
```

7 Create Maps Based on Non-Leveled Flight Lines

```
[ ]: interp_type = 'RBF'
interp_df = pu.interp_flight_lines(anomaly_df      = log_df[(log_df.LAT >= MIN_MAP_LAT) & (log_df.LAT <= MAX_MAP_LAT)],
                                    dx              = DX,
                                    dy              = DY,
                                    max_terrain_msl = MAX_TERRAIN_MSL,
                                    buffer          = 0,
                                    interp_type     = interp_type,
                                    neighbors       = None,
                                    skip_na_mask   = True)

interp_lats    = interp_df['LAT']
```

```

interp_lons      = interp_df['LONG']
interp_scalar   = interp_df['F']
interp_heights  = interp_df['ALT']
interp_std       = interp_df['STD']

interp_scalar_LPF = filt.lpf2(interp_scalar,
                               MAX_SURVEY_AGL,
                               DX,
                               DY)

map_title = '{}\nNon-Leveled Anomaly Map\nUsing {} Interpolation'.
            format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar,
                     cmap=cmap,
                     alpha=alpha)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)

map_title = '{}\nNon-Leveled Anomaly Map\nUsing {} Interpolation (Filtered)'.
            format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar_LPF,
                     cmap=cmap,
                     alpha=alpha)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)

extent = [interp_lons.min(), interp_lats.min(), interp_lons.max(), interp_lats.
          max()]
xmin, ymin, xmax, ymax = extent

```

```

flight_path = np.hstack([np.array(log_df.LAT)[:, np.newaxis],
                        np.array(log_df.LONG)[:, np.newaxis],
                        np.array(log_df.ALT)[:, np.newaxis],
                        np.array(log_df.epoch_sec)[:, np.newaxis]]))

area_polys = [{'NAME': 'Survey Area',
               'FL_DIRFL_DISTTL_DIRTL_DISTLATLONGALT# Export map as a GeoTIFF
map = mu.export_map(out_dir
                     location = OUT_DIR,
                     date = ' '.join(map_title.split()),
                     lats = interp_lats,
                     lons = interp_lons,
                     scalar = interp_scalar_LPF,
                     heights = interp_heights,
                     process_df = pd.DataFrame(process_dict),
                     process_app = PROCESS_APP,
                     stds = interp_std,
                     vector = None,
                     scalar_type = SCALAR_TYPE,
                     vector_type = VECTOR_TYPE,
                     scalar_var = np.nan,
                     vector_var = np.nan,
                     poc = POC,
                     flight_path = flight_path,
                     area_polys = area_polys,
                     osm_path = None,
                     level_type = 'No leveling',
                     tl_coeff_types = TL_COEFF_TYPES,
                     tl_coeffs = TL_C,
                     interp_type = interp_type,
                     final_filt_cut = FINAL_FILT_CUT,
                     final_filt_order = FINAL_FILT_ORDER)

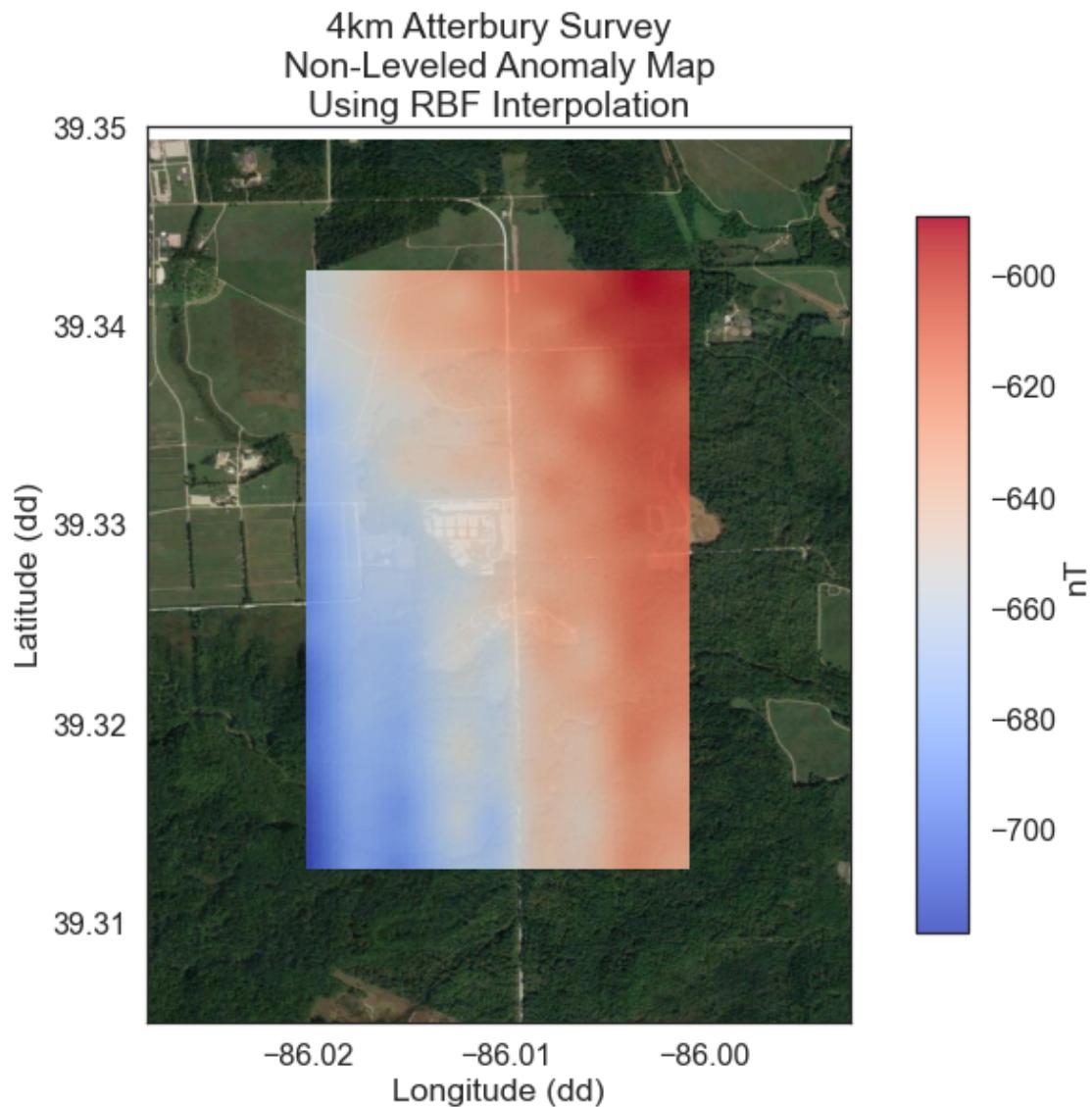
plt.figure()
map[0].plot(cmap=cm.coolwarm)
plt.title('Map From Exported GeoTIFF')

```

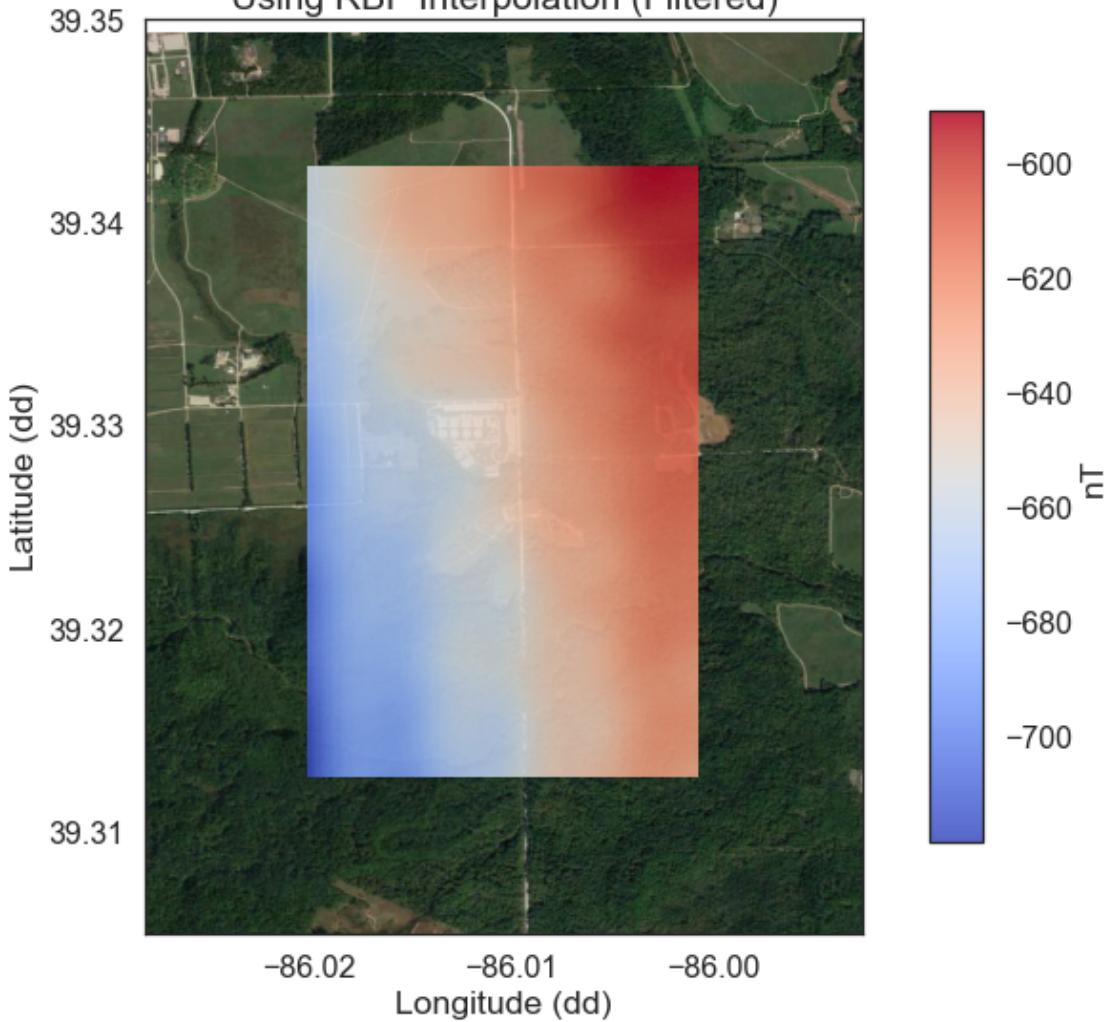
Interpolating survey anomaly data to map coordinates

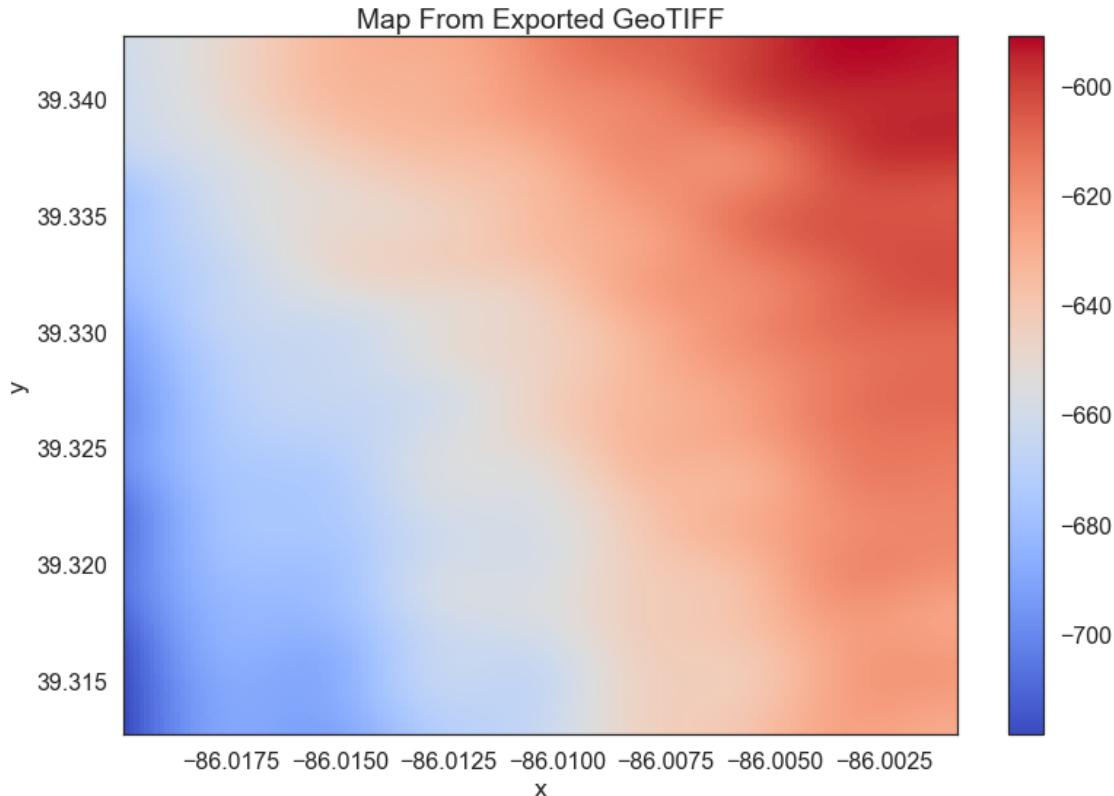
Running radial basis function (RBF) interpolation for all map pixels

[]: Text(0.5, 1.0, 'Map From Exported GeoTIFF')



4km Atterbury Survey
Non-Leveled Anomaly Map
Using RBF Interpolation (Filtered)



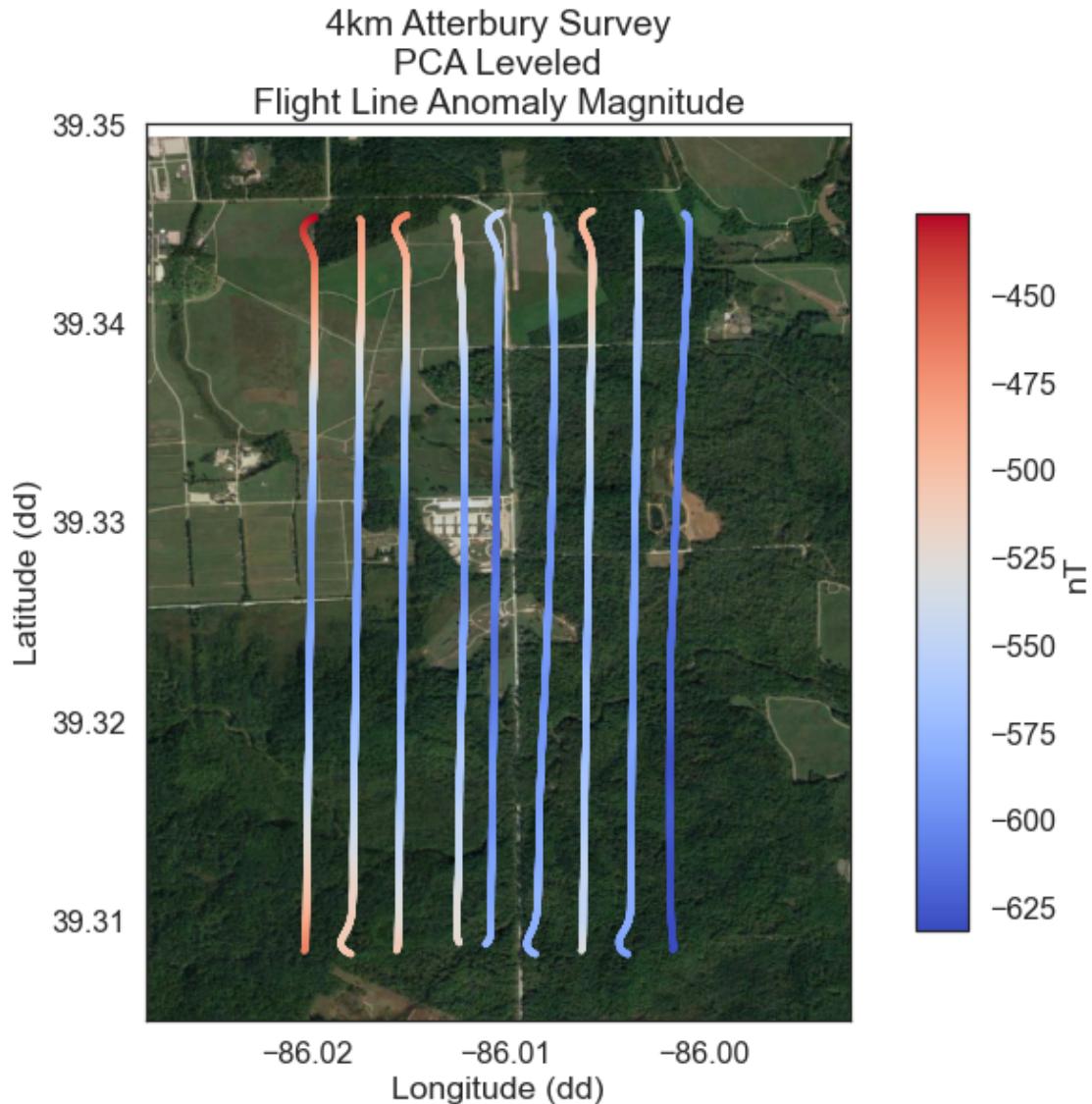


8 Apply PCA-Based Flight Line Leveling

```
[ ]: lvld_survey_df = pcaLvl.pca_lvl(survey_df = log_df,
                                      num_ptls = 2,
                                      ptl_locs = np.array([0.25, 0.75]))

plt.figure()
plt.title('{}\nPCA Leveled\nFlight Line Anomaly Magnitude'.format(SURVEY_NAME))
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.scatter(lvld_survey_df.LONG[lvld_survey_df.LINE_TYPE == 1],
                  lvld_survey_df.LAT[lvld_survey_df.LINE_TYPE == 1],
                  s=s,
                  c=lvld_survey_df.F[lvld_survey_df.LINE_TYPE == 1],
                  cmap=cmap)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)
```

[]: (39.305, 39.35)



9 Create Maps Based on PCA-Leveled Flight Lines

```
[ ]: interp_type = 'RBF'  
interp_df = pu.interp_flight_lines(anomaly_df  
    ↪lvld_survey_df[(lvld_survey_df.LAT >= MIN_MAP_LAT) & (lvld_survey_df.LAT <=  
    ↪MAX_MAP_LAT)],  
                                    dx          = DX,  
                                    dy          = DY,  
                                    max_terrain_msl = MAX_TERRAIN_MSL,
```

```

        buffer      = 0,
        interp_type = interp_type,
        neighbors   = None,
        skip_na_mask = True)

interp_lats    = interp_df['LAT']
interp_lons    = interp_df['LONG']
interp_scalar  = interp_df['F']
interp_heights = interp_df['ALT']
interp_std     = interp_df['STD']

interp_scalar_LPF = filt.lpf2(interp_scalar,
                               MAX_SURVEY_AGL,
                               DX,
                               DY)

map_title = '{}\nPCA Leveled Anomaly Map\nUsing {} Interpolation'.
            format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar,
                     cmap=cmap,
                     alpha=alpha)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)

map_title = '{}\nPCA Leveled Anomaly Map\nUsing {} Interpolation (Filtered)'.
            format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar_LPF,
                     cmap=cmap,
                     alpha=alpha)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)

```

```

plt.xlim(xlims)
plt.ylim(ylims)

process_dict['F_CAL_IGRF_TEMPORAL_FILT_LEVEL'] = lvld_survey_df.F

# Export map as a GeoTIFF
map = mu.export_map(out_dir
                     = OUT_DIR,
                     location = ' '.join(map_title.split()),
                     date = log_df.datetime[0],
                     lats = interp_lats,
                     lons = interp_lons,
                     scalar = interp_scalar_LPF,
                     heights = interp_heights,
                     process_df = pd.DataFrame(process_dict),
                     process_app = PROCESS_APP,
                     stds = interp_std,
                     vector = None,
                     scalar_type = SCALAR_TYPE,
                     vector_type = VECTOR_TYPE,
                     scalar_var = np.nan,
                     vector_var = np.nan,
                     poc = POC,
                     flight_path = flight_path,
                     area_polys = area_polys,
                     osm_path = None,
                     level_type = 'PCA pseudo tie line leveling',
                     tl_coeff_types = TL_COEFF_TYPES,
                     tl_coeffs = TL_C,
                     interp_type = interp_type,
                     final_filt_cut = FINAL_FILT_CUT,
                     final_filt_order = FINAL_FILT_ORDER)

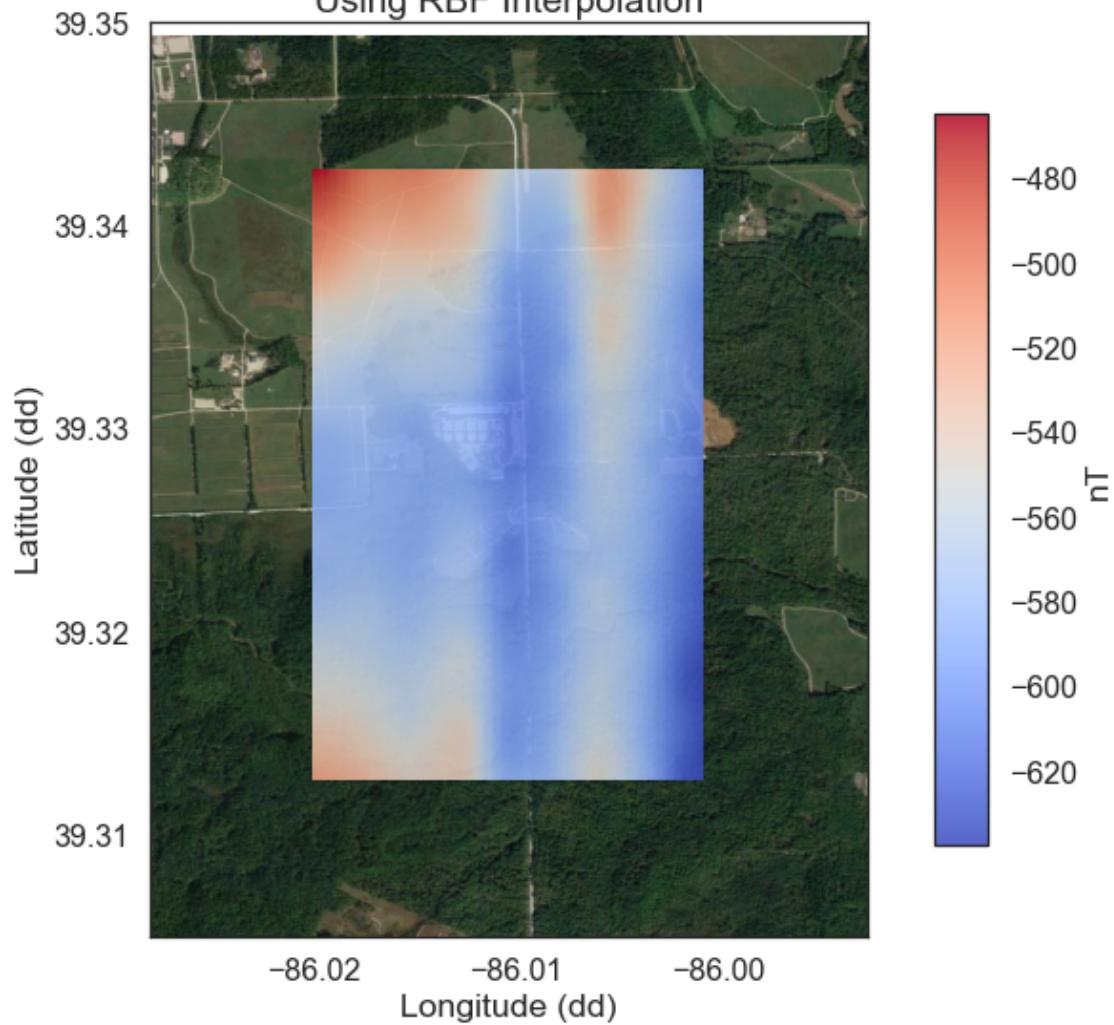
plt.figure()
map[0].plot(cmap=cm.coolwarm)
plt.title('Map From Exported GeoTIFF')

```

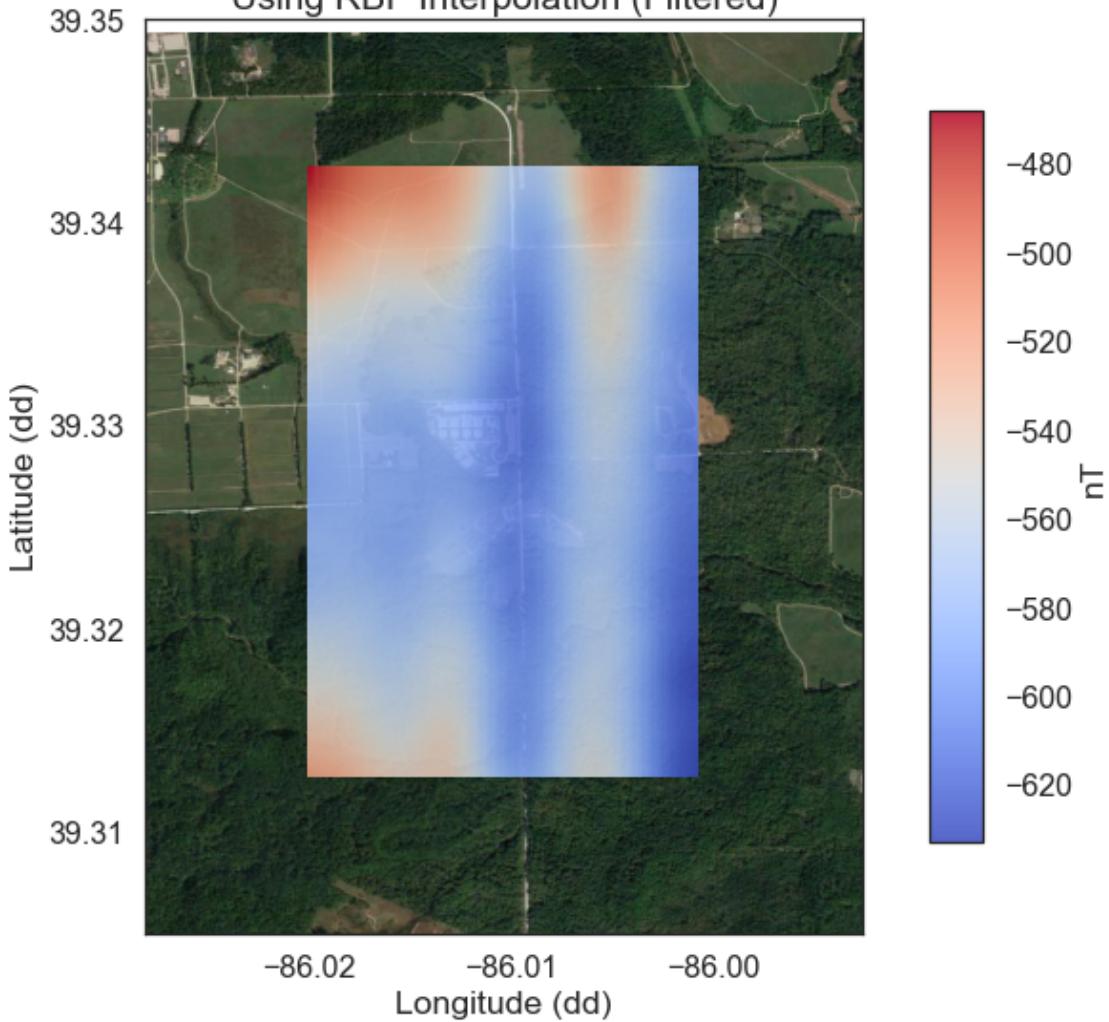
Interpolating survey anomaly data to map coordinates
Running radial basis function (RBF) interpolation for all map pixels

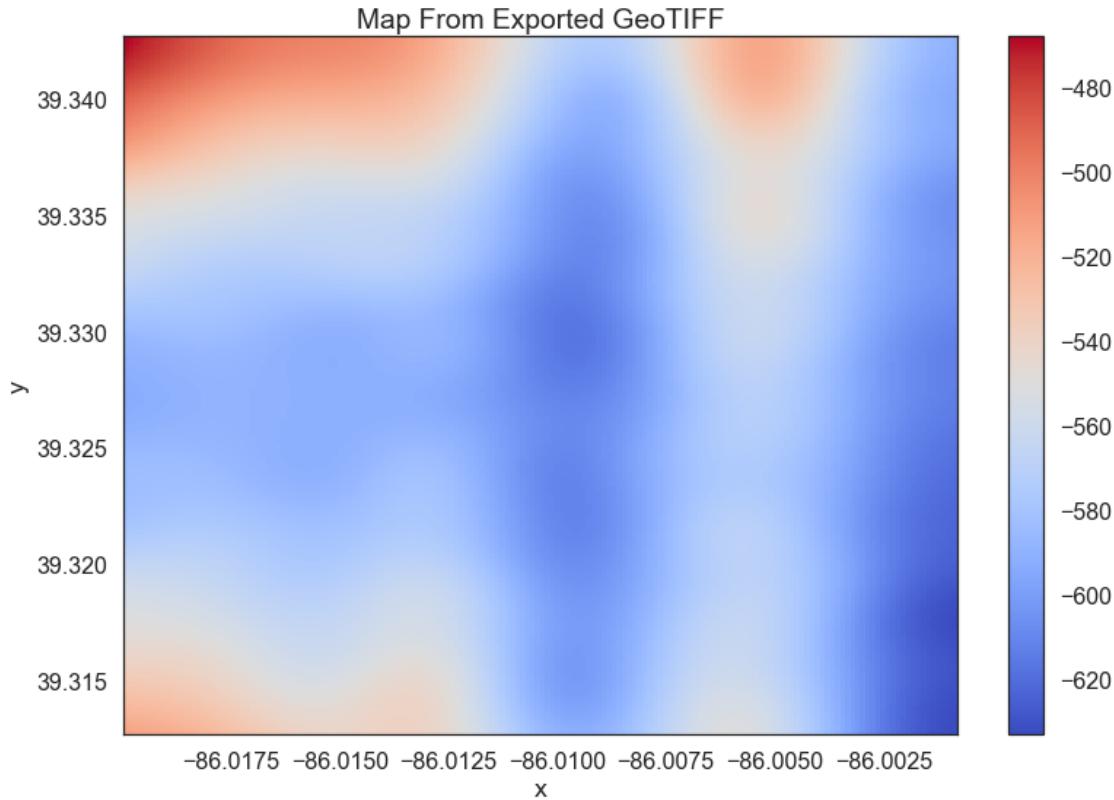
[]: Text(0.5, 1.0, 'Map From Exported GeoTIFF')

4km Atterbury Survey
PCA Leveled Anomaly Map
Using RBF Interpolation



4km Atterbury Survey
PCA Leveled Anomaly Map
Using RBF Interpolation (Filtered)



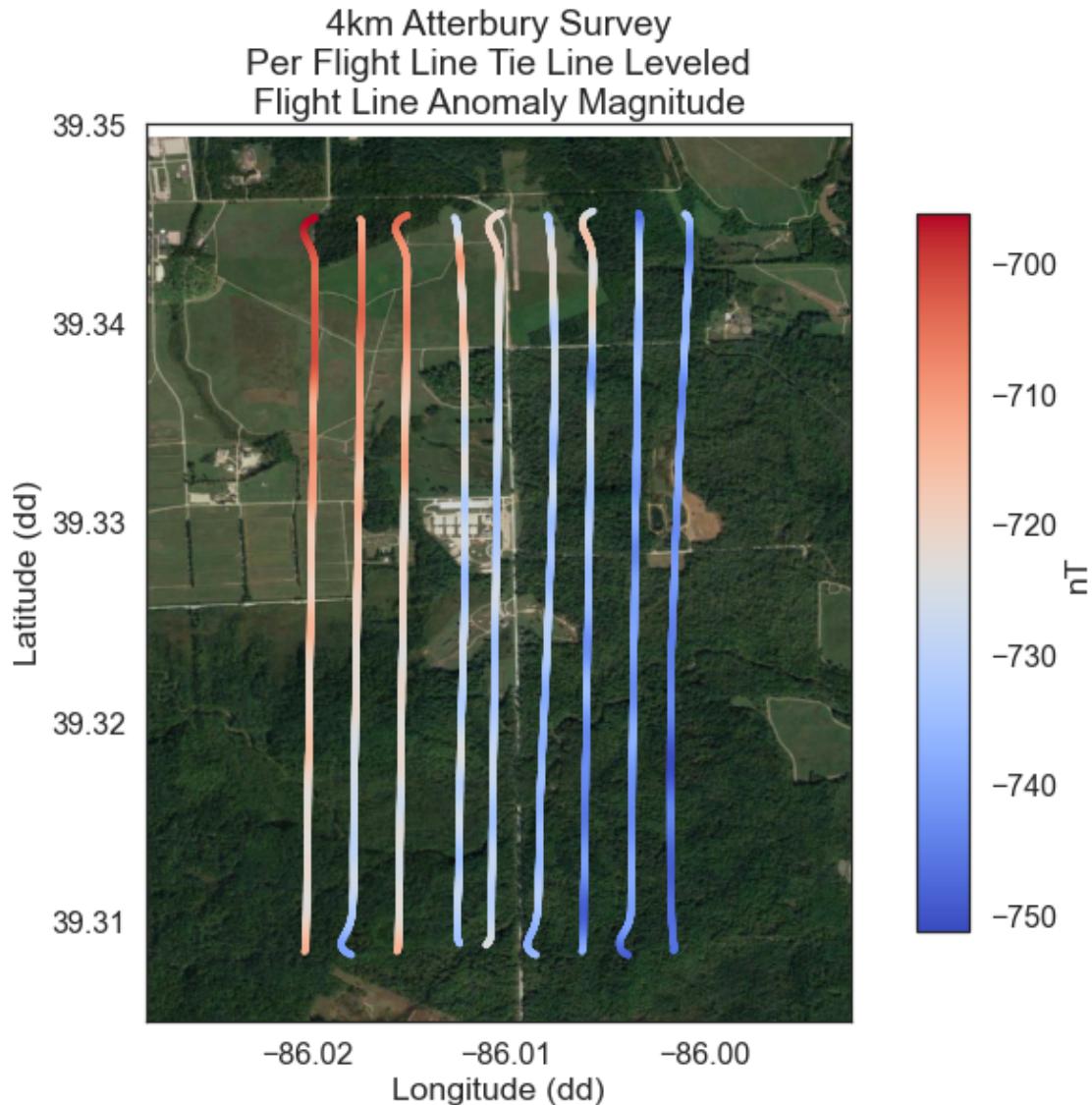


10 Apply Per Flight Line Tie Line-Based Flight Line Leveling

```
[ ]: lvld_survey_df = tieLvl.tie_lvl(survey_df = log_df,
                                     approach = 'lobf')

plt.figure()
plt.title('{}\nPer Flight Line Tie Line Leveled\nFlight Line Anomaly Magnitude'.
          .format(SURVEY_NAME))
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.scatter(lvld_survey_df.LONG[lvld_survey_df.LINE_TYPE == 1],
                 lvld_survey_df.LAT[lvld_survey_df.LINE_TYPE == 1],
                 s=s,
                 c=lvld_survey_df.F[lvld_survey_df.LINE_TYPE == 1],
                 cmap=cmap)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)
```

[]: (39.305, 39.35)



11 Create Map Based on Per Flight Line Tie Line-Leveled Flight Lines

```
[ ]: interp_type = 'RBF'  
interp_df = pu.interp_flight_lines(anomaly_df  
    ↪lvld_survey_df[(lvld_survey_df.LAT >= MIN_MAP_LAT) & (lvld_survey_df.LAT <=  
    ↪MAX_MAP_LAT)],  
                                    dx = DX,  
                                    dy = DY,
```

```

        max_terrain_msl = MAX_TERRAIN_MSL,
        buffer          = 0,
        interp_type     = interp_type,
        neighbors       = None,
        skip_na_mask    = True)

interp_lats   = interp_df['LAT']
interp_lons   = interp_df['LONG']
interp_scalar = interp_df['F']
interp_heights = interp_df['ALT']
interp_std    = interp_df['STD']

interp_scalar_LPF = filt.lpf2(interp_scalar,
                               MAX_SURVEY_AGL,
                               DX,
                               DY)

map_title = '{}\nPer Flight Line Tie Line Leveled Anomaly Map\nUsing {} ↵
↪Interpolation'.format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar,
                     cmap=cmap,
                     alpha=alpha)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)

map_title = '{}\nPer Flight Line Tie Line Leveled Anomaly Map\nUsing {} ↵
↪Interpolation (Filtered)'.format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar_LPF,
                     cmap=cmap,
                     alpha=alpha)

```

```

plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)

process_dict['F_CAL_IGRF_TEMPORAL_filt_LEVEL'] = lvld_survey_df.F

# Export map as a GeoTIFF
map = mu.export_map(out_dir
                     location      = OUT_DIR,
                     date          = ' '.join(map_title.split()),
                     lats          = interp_lats,
                     lons          = interp_lons,
                     scalar         = interp_scalar_LPF,
                     heights        = interp_heights,
                     process_df    = pd.DataFrame(process_dict),
                     process_app   = PROCESS_APP,
                     stds          = interp_std,
                     vector         = None,
                     scalar_type   = SCALAR_TYPE,
                     vector_type   = VECTOR_TYPE,
                     scalar_var    = np.nan,
                     vector_var    = np.nan,
                     poc            = POC,
                     flight_path   = flight_path,
                     area_polys    = area_polys,
                     osm_path       = None,
                     level_type    = 'Per flight line tie line leveling',
                     tl_coeff_types = TL_COEFF_TYPES,
                     tl_coeffs     = TL_C,
                     interp_type   = interp_type,
                     final_filt_cut = FINAL_FILT_CUT,
                     final_filt_order = FINAL_FILT_ORDER)

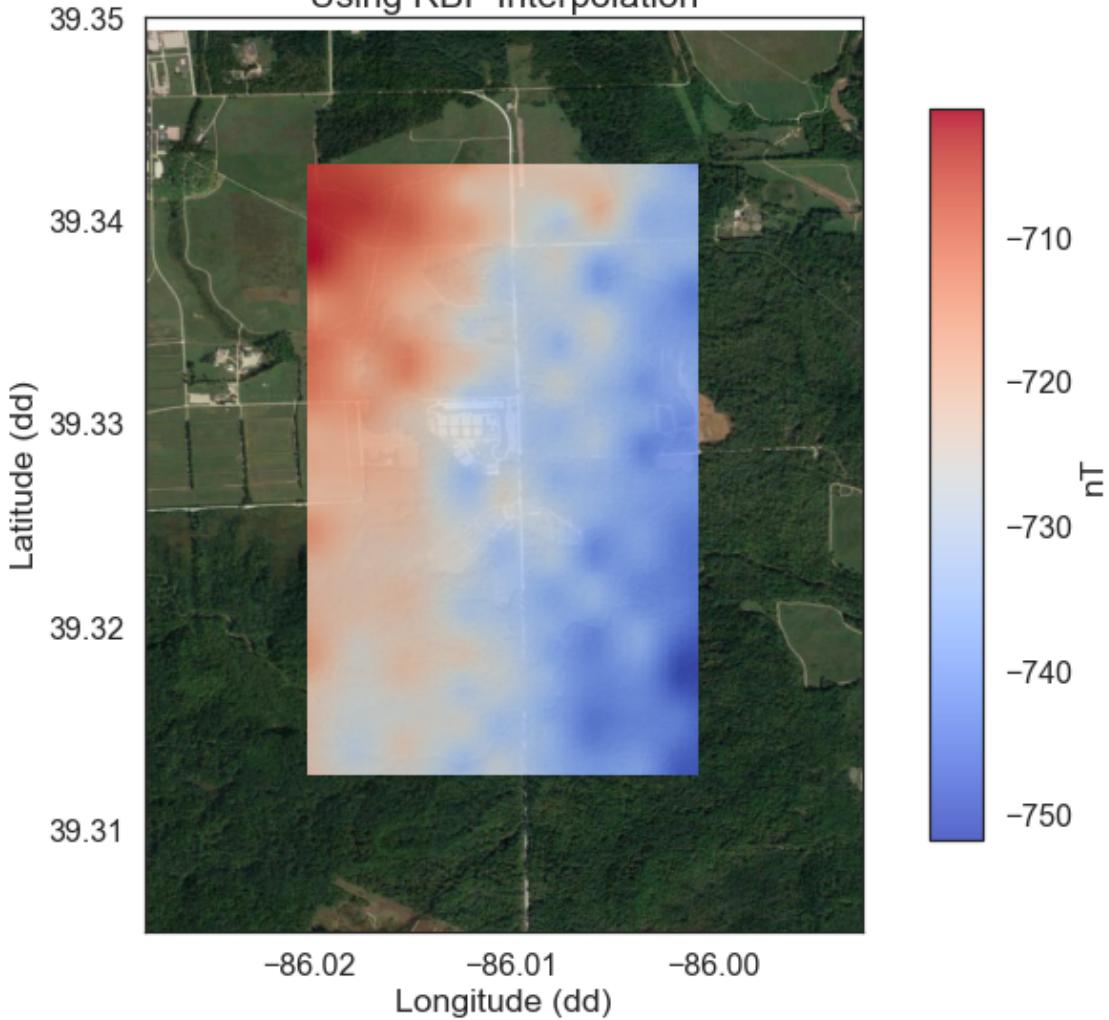
plt.figure()
map[0].plot(cmap=cm.coolwarm)
plt.title('Map From Exported GeoTIFF')

```

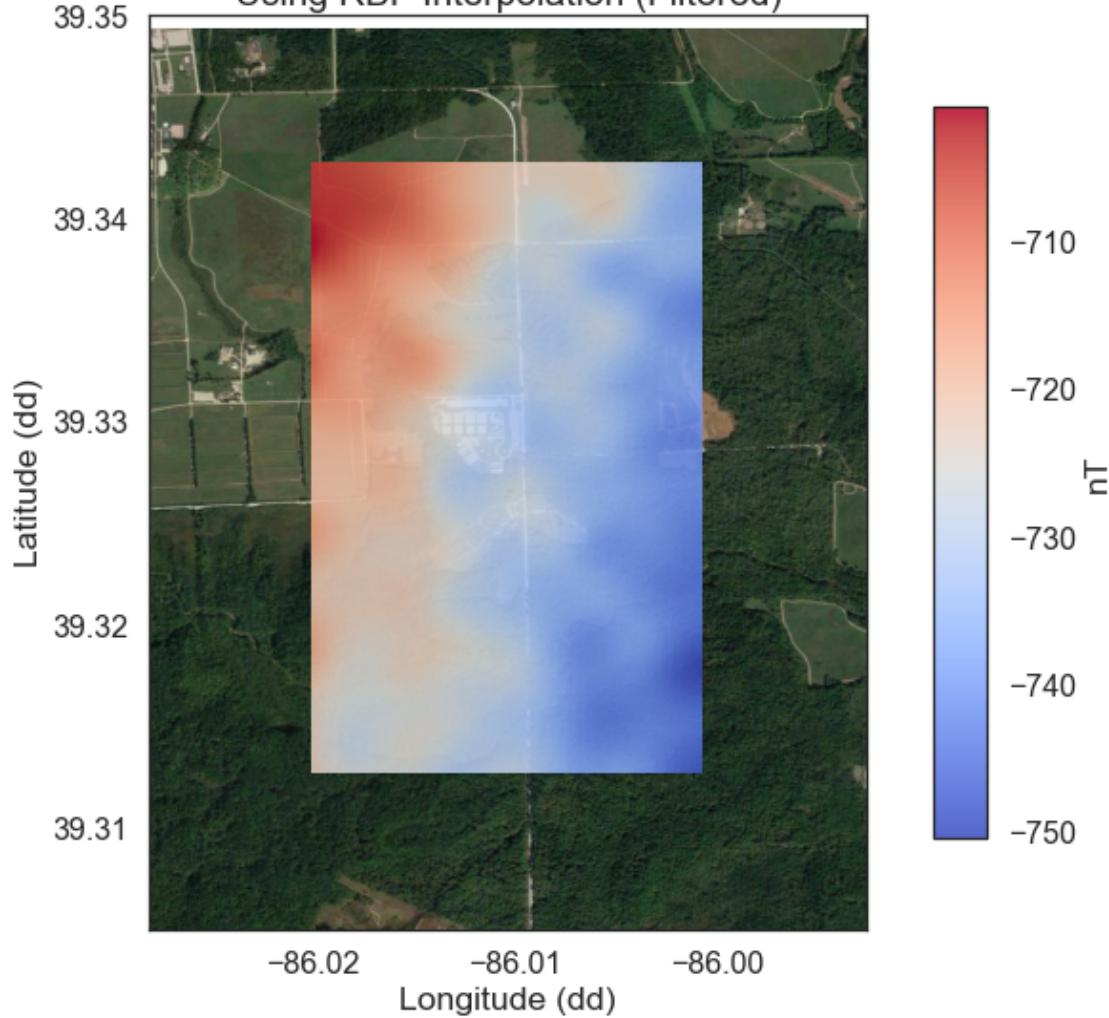
Interpolating survey anomaly data to map coordinates
Running radial basis function (RBF) interpolation for all map pixels

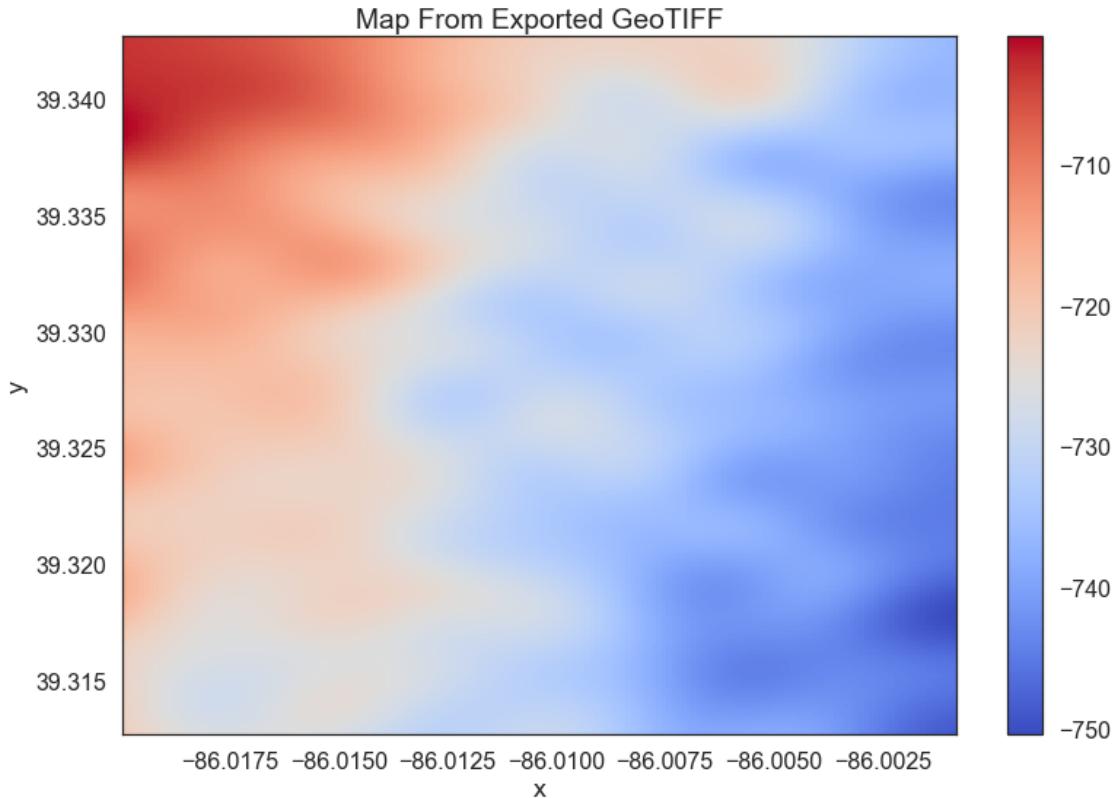
[]: Text(0.5, 1.0, 'Map From Exported GeoTIFF')

4km Atterbury Survey
Per Flight Line Tie Line Leveled Anomaly Map
Using RBF Interpolation



4km Atterbury Survey
Per Flight Line Tie Line Leveled Anomaly Map
Using RBF Interpolation (Filtered)



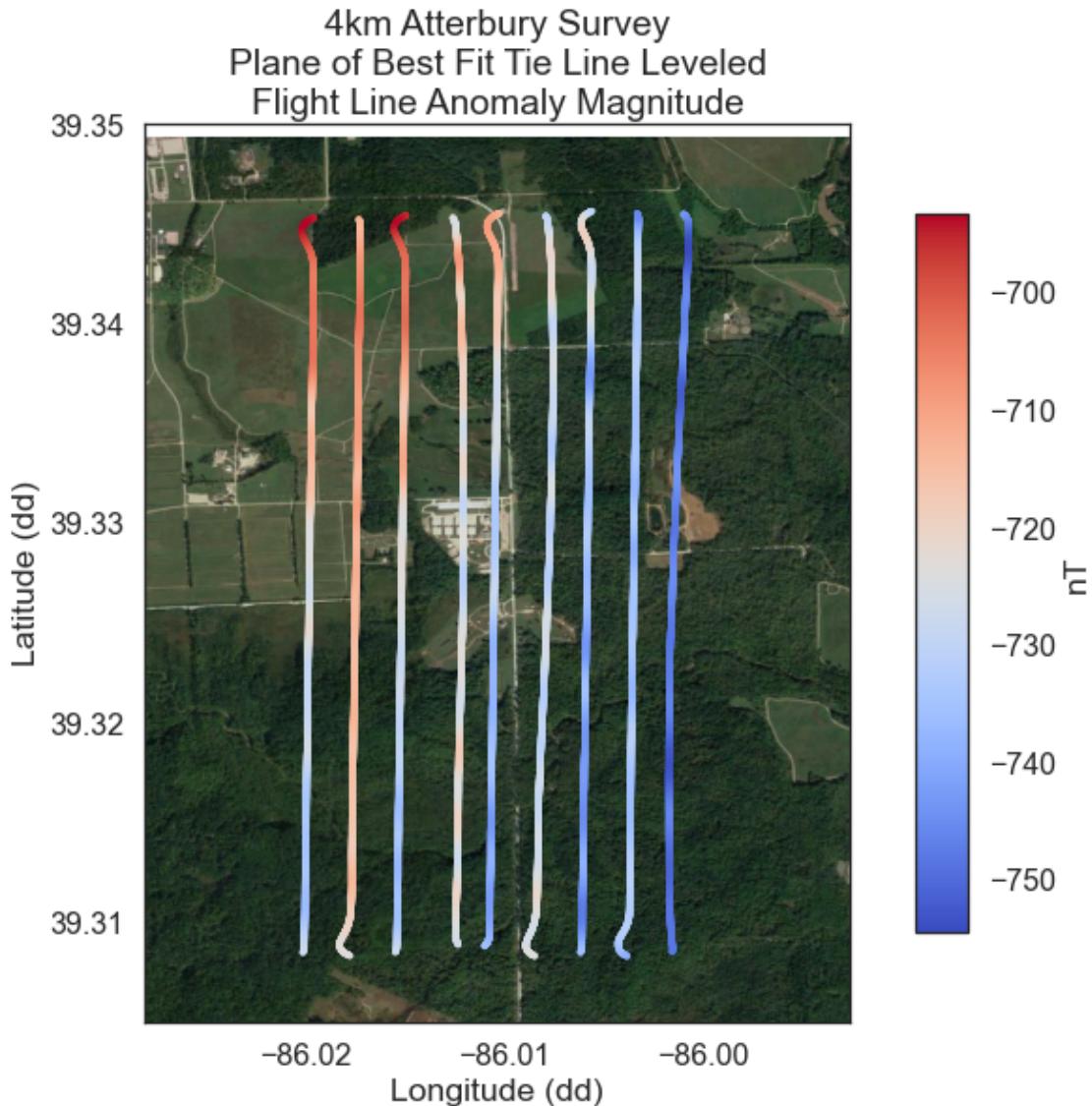


12 Apply Plane of Best Fit Tie Line-Based Flight Line Leveling

```
[ ]: lvld_survey_df = tieLvl.tie_lvl(survey_df = log_df,
                                     approach = 'lsq')

plt.figure()
plt.title('{}\nPlane of Best Fit Tie Line Leveled\nFlight Line Anomaly\nMagnitude'.format(SURVEY_NAME))
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.scatter(lvld_survey_df.LONG[lvld_survey_df.LINE_TYPE == 1],
                 lvld_survey_df.LAT[lvld_survey_df.LINE_TYPE == 1],
                 s=s,
                 c=lvld_survey_df.F[lvld_survey_df.LINE_TYPE == 1],
                 cmap=cmap)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)
```

[]: (39.305, 39.35)



13 Create Map Based on Plane of Best Fit Tie Line-Leveled Flight Lines

```
[ ]: interp_type = 'RBF'  
interp_df = pu.interp_flight_lines(anomaly_df  
    ↪lvld_survey_df[(lvld_survey_df.LAT >= MIN_MAP_LAT) & (lvld_survey_df.LAT <=  
    ↪MAX_MAP_LAT)],  
                                    dx = DX,  
                                    dy = DY,
```

```

        max_terrain_msl = MAX_TERRAIN_MSL,
        buffer          = 0,
        interp_type     = interp_type,
        neighbors       = None,
        skip_na_mask    = True)

interp_lats   = interp_df['LAT']
interp_lons   = interp_df['LONG']
interp_scalar = interp_df['F']
interp_heights = interp_df['ALT']
interp_std    = interp_df['STD']

interp_scalar_LPF = filt.lpf2(interp_scalar,
                               MAX_SURVEY_AGL,
                               DX,
                               DY)

map_title = '{}\nPlane of Best Fit Tie Line Leveled Anomaly Map\nUsing {} ↵
Interpolation'.format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar,
                     cmap=cmap,
                     alpha=alpha)
plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)

map_title = '{}\nPlane of Best Fit Tie Line Leveled Anomaly Map\nUsing {} ↵
Interpolation (Filtered)'.format(SURVEY_NAME, interp_type)

plt.figure()
plt.title(map_title)
plt.xlabel('Longitude (dd)')
plt.ylabel('Latitude (dd)')
plt.imshow(img, extent=GMAP_EXTENT)
cb = plt.pcolormesh(interp_lons,
                     interp_lats,
                     interp_scalar_LPF,
                     cmap=cmap,
                     alpha=alpha)

```

```

plt.colorbar(cb, label='nT', shrink=shrink, aspect=aspect)
plt.xlim(xlims)
plt.ylim(ylims)

process_dict['F_CAL_IGRF_TEMPORAL_FILT_LEVEL'] = lvld_survey_df.F

# Export map as a GeoTIFF
map = mu.export_map(out_dir
                     location      = OUT_DIR,
                     date          = ' '.join(map_title.split()),
                     lats          = interp_lats,
                     lons          = interp_lons,
                     scalar         = interp_scalar_LPF,
                     heights        = interp_heights,
                     process_df     = pd.DataFrame(process_dict),
                     process_app    = PROCESS_APP,
                     stds          = interp_std,
                     vector         = None,
                     scalar_type    = SCALAR_TYPE,
                     vector_type    = VECTOR_TYPE,
                     scalar_var     = np.nan,
                     vector_var     = np.nan,
                     poc            = POC,
                     flight_path    = flight_path,
                     area_polys     = area_polys,
                     osm_path        = None,
                     level_type     = 'Plane of best fit tie line leveling',
                     tl_coeff_types = TL_COEFF_TYPES,
                     tl_coeffs       = TL_C,
                     interp_type     = interp_type,
                     final_filt_cut  = FINAL_FILT_CUT,
                     final_filt_order = FINAL_FILT_ORDER)

plt.figure()
map[0].plot(cmap=cm.coolwarm)
plt.title('Map From Exported GeoTIFF')

```

Interpolating survey anomaly data to map coordinates
Running radial basis function (RBF) interpolation for all map pixels

[]: Text(0.5, 1.0, 'Map From Exported GeoTIFF')

4km Atterbury Survey
Plane of Best Fit Tie Line Leveled Anomaly Map
Using RBF Interpolation

