In [1]:

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# ======================================================
# Importation of Libraries
#
# Michael Collins, Flatiron School
# 2020-10-30_0639_MDT
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import math
from IPython.display import display
from openlocationcode import openlocationcode as olc
from geographiclib.geodesic import Geodesic
import numpy as np
import pandas as pd
from datetime import datetime
import itertools
import warnings
warnings.filterwarnings('ignore')
import scipy.stats as scs
from scipy.stats import median_abs_deviation as MAD
import statsmodels.api as sm
from sklearn.datasets import make_regression
import matplotlib.pyplot as plt
import seaborn as sns
import flatiron.statsFunctions as sf
from importlib import reload
reload(sf)
import plotly.express as px
import requests

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In [2]:

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# ======================================================
# K-Nearest-Neighbor Evaluation
#
# Suppose we are given:
#       * a number of events "N"
#       * a list of event indices "event_i"
#       * a list of event coordinates "event_latlng"
#       * some number of events "K" < N
#       * the coordinates "Q_latlng" of some arbitrary
#             point Q on earth's surface
#
# The code in this cell returns [the list of indices for
# the K events whose proximity is nearest to point Q]
# for each of the N events.
#
# Michael Collins, Flatiron School
# 2020-10-28_0524_MDT
#
# ======================================================

OLC_CODE_PLANET = "00000000+"
OLC_EARTH_CIRCUMFERENCE = np.round(2 * np.pi * Geodesic.WGS84.a, 3)
OLC_LATITUDE_SPAN = 180.0
OLC_LATITUDE_SOUTH_POLE = -90.0
OLC_LATITUDE_EQUATOR = 0.0
OLC_LATITUDE_NORTH_POLE = 90.0
OLC_LONGITUDE_SPAN = 360.0
OLC_LONGITUDE_DATELINE_WEST = -180.0
OLC_LONGITUDE_GREENWICH = 0.0
OLC_LONGITUDE_DATELINE_EAST = 180.0

OLC_PYLON_MIDPOINT = "midpoint"
OLC_PYLON_O = OLC_PYLON_MIDPOINT
OLC_PYLON_N = "pylon_N"
OLC_PYLON_NE = "pylon_NE"
OLC_PYLON_E = "pylon_E"
OLC_PYLON_SE = "pylon_SE"
OLC_PYLON_S = "pylon_S"
OLC_PYLON_SW = "pylon_SW"
OLC_PYLON_W = "pylon_W"
OLC_PYLON_NW = "pylon_NW"
OLC_BORDER_PYLONs = [OLC_PYLON_N, OLC_PYLON_NE, OLC_PYLON_E, OLC_PYLON_SE,
                     OLC_PYLON_S, OLC_PYLON_SW, OLC_PYLON_W, OLC_PYLON_NW]
OLC_PYLONs = [OLC_PYLON_O] + OLC_BORDER_PYLONs

OLC_OFFSET_N = "offset_N"
OLC_OFFSET_NE = "offset_NE"
OLC_OFFSET_E = "offset_E"
OLC_OFFSET_SE = "offset_SE"
OLC_OFFSET_S = "offset_S"
OLC_OFFSET_SW = "offset_SW"
OLC_OFFSET_W = "offset_W"
OLC_OFFSET_NW = "offset_NW"
OLC_CARDINAL_OFFSETs = [OLC_OFFSET_N, OLC_OFFSET_E, OLC_OFFSET_S, OLC_OFFSET_W]
OLC_DIAGONAL_OFFSETs = [OLC_OFFSET_NE, OLC_OFFSET_SE, OLC_OFFSET_SW, OLC_OFFSET_NW]
OLC_OFFSETs = [OLC_OFFSET_N, OLC_OFFSET_NE, OLC_OFFSET_E, OLC_OFFSET_SE,
               OLC_OFFSET_S, OLC_OFFSET_SW, OLC_OFFSET_W, OLC_OFFSET_NW]

OLC_TAU_PLANET = 0    # (180)-degree by (360)-degree resolution
OLC_TAU_DOMAIN = 1    # (20)-degree by (20)-degree resolution
OLC_TAU_SHIRE = 2     # (1)-degree by (1)-degree resolution
OLC_TAU_TOWNSHIP = 3  # (1/20)-degree by (1/20)-degree resolution
OLC_TAU_HOLLER = 4    # (1/400)-degree by (1/400)-degree resolution
OLC_TAU_ROOFTOP = 5   # (1/8000)-degree by (1/8000)-degree resolution
OLC_TAU_PARLOR = 6    # (1/40000)-degree by (1/32000)-degree resolution
OLC_TAU_DESK = 7      # subdivides the above into a 5-tall by 4-wide grid
OLC_TAU_ENVELOPE = 8  # subdivides the above into a 5-tall by 4-wide grid
OLC_TAU_ERASER = 9    # subdivides the above into a 5-tall by 4-wide grid
OLC_TAU_STAPLE = 10   # subdivides the above into a 5-tall by 4-wide grid
OLC_TAUs = [OLC_TAU_PLANET, OLC_TAU_DOMAIN, OLC_TAU_SHIRE,
            OLC_TAU_TOWNSHIP, OLC_TAU_HOLLER, OLC_TAU_ROOFTOP,
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            OLC_TAU_PARLOR, OLC_TAU_DESK, OLC_TAU_ENVELOPE,
            OLC_TAU_ERASER, OLC_TAU_STAPLE]

OLC_TAU_BEDROCK = OLC_TAU_ROOFTOP
OLC_GRID_NORTH_MAX = np.prod([9, 20, 20, 20, 20][0:OLC_TAU_BEDROCK])
OLC_GRID_EAST_MAX = np.prod([18, 20, 20, 20, 20][0:OLC_TAU_BEDROCK])


OLC_TIER_PLANET = "planet"      # (180)-degree by (360)-degree resolution
OLC_TIER_DOMAIN = "domain"      # (20)-degree by (20)-degree resolution
OLC_TIER_SHIRE = "shire"        # (1)-degree by (1)-degree resolution
OLC_TIER_TOWNSHIP = "township"  # (1/20)-degree by (1/20)-degree resolution
OLC_TIER_HOLLER = "holler"      # (1/400)-degree by (1/400)-degree resolution
OLC_TIER_ROOFTOP = "rooftop"    # (1/8000)-degree by (1/8000)-degree resolution
OLC_TIER_PARLOR = "parlor"      # (1/40000)-degree by (1/32000)-degree resolution
OLC_TIER_DESK = "desk"          # subdivides the above into a 5-tall by 4-wide grid
OLC_TIER_ENVELOPE = "envelope"  # subdivides the above into a 5-tall by 4-wide grid
OLC_TIER_ERASER = "eraser"      # subdivides the above into a 5-tall by 4-wide grid
OLC_TIER_STAPLE = "staple"      # subdivides the above into a 5-tall by 4-wide grid
OLC_TIERs = [OLC_TIER_PLANET, OLC_TIER_DOMAIN, OLC_TIER_SHIRE,
             OLC_TIER_TOWNSHIP, OLC_TIER_HOLLER, OLC_TIER_ROOFTOP,
             OLC_TIER_PARLOR, OLC_TIER_DESK, OLC_TIER_ENVELOPE,
             OLC_TIER_ERASER, OLC_TIER_STAPLE]

OLC_CODELEN_PLANET = 0      # (180)-degree by (360)-degree resolution
OLC_CODELEN_DOMAIN = 2      # (20)-degree by (20)-degree resolution
OLC_CODELEN_SHIRE = 4        # (1)-degree by (1)-degree resolution
OLC_CODELEN_TOWNSHIP = 6  # (1/20)-degree by (1/20)-degree resolution
OLC_CODELEN_HOLLER = 8      # (1/400)-degree by (1/400)-degree resolution
OLC_CODELEN_ROOFTOP = 10    # (1/8000)-degree by (1/8000)-degree resolution
OLC_CODELEN_PARLOR = 11      # (1/40000)-degree by (1/32000)-degree resolution
OLC_CODELEN_DESK = 12          # subdivides the above into a 5-tall by 4-wide grid
OLC_CODELEN_ENVELOPE = 13  # subdivides the above into a 5-tall by 4-wide grid
OLC_CODELEN_ERASER = 14      # subdivides the above into a 5-tall by 4-wide grid
OLC_CODELEN_STAPLE = 15      # subdivides the above into a 5-tall by 4-wide grid
OLC_CODELENs = [OLC_CODELEN_PLANET, OLC_CODELEN_DOMAIN, OLC_CODELEN_SHIRE,
                OLC_CODELEN_TOWNSHIP, OLC_CODELEN_HOLLER, OLC_CODELEN_ROOFTOP,
                OLC_CODELEN_PARLOR, OLC_CODELEN_DESK, OLC_CODELEN_ENVELOPE,
                OLC_CODELEN_ERASER, OLC_CODELEN_STAPLE]

OLC_tau_to_tier = dict(zip(OLC_TAUs, OLC_TIERs))
OLC_tier_to_tau = dict(zip(OLC_TIERs, OLC_TAUs))
OLC_TIER_BEDROCK = OLC_tau_to_tier[OLC_TAU_BEDROCK]

OLC_tau_to_codeLen = dict(zip(OLC_TAUs, OLC_CODELENs))

OLC_codeLen_to_tau = dict(zip(OLC_CODELENs, OLC_TAUs))

OLC_tier_to_codeLen = dict(zip(OLC_TIERs, OLC_CODELENs))

OLC_codeLen_to_tier = dict(zip(OLC_CODELENs, OLC_TIERs))

def sci_round(x, n):
    s = np.format_float_scientific(x, precision=n, trim='-')
    return float(s)

def olc_encode_tau(latlng, tau):
    if not tau in OLC_TAUs:
        return None

    if tau == OLC_TAU_PLANET:
        code = OLC_CODE_PLANET
    else:
        code = olc.encode(*latlng, OLC_tau_to_codeLen[tau])
    return code

def olc_add_zone_to_archive(this_zone):
    raw_dict = {}
    raw_dict[this_zone.code] = this_zone
    for child_zone in this_zone.children.values():
        child_dict = olc_add_zone_to_archive(child_zone)
        raw_dict.update(child_dict)
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    return dict(sorted(raw_dict.items()))

def olc_latitude_to_iNorth_fracN(latitude=None):
    if not isinstance(latitude, float):
        print(f"the latitude must be specified.")
        return None
    if not(OLC_LATITUDE_SOUTH_POLE <= latitude <= OLC_LATITUDE_NORTH_POLE):
        print(f"the latitude {latitude} is not valid.")
        return None
    if latitude == OLC_LATITUDE_SOUTH_POLE:
        return (0, 0.0)
    if latitude == OLC_LATITUDE_NORTH_POLE:
        return (OLC_GRID_NORTH_MAX - 1, 1.0)
    uNorth = sci_round((latitude - OLC_LATITUDE_SOUTH_POLE)*OLC_GRID_NORTH_MAX/OLC_LATITUDE_SPAN, 10)
    fN, iN = np.modf(uNorth)
    iNorth = int(iN)
    fracN = float(fN)
    return (iNorth, fracN)

def olc_longitude_to_iEast_fracE(longitude=None):
    if not isinstance(longitude, float):
        print(f"the longitude must be specified.")
        return None
    if not(OLC_LONGITUDE_DATELINE_WEST <= longitude <= OLC_LONGITUDE_DATELINE_EAST):
        print(f"the longitude {longitude} is not valid.")
        return None
    if longitude == OLC_LONGITUDE_DATELINE_WEST:
        return (0, 0.0)
    if longitude == OLC_LONGITUDE_DATELINE_EAST:
        return (OLC_GRID_EAST_MAX - 1, 1.0)
    uEast = sci_round((longitude - OLC_LONGITUDE_DATELINE_WEST)*OLC_GRID_EAST_MAX/OLC_LONGITUDE_SPAN, 10)
    fE, iE = np.modf(uEast)
    iEast = int(iE)
    fracE = float(fE)
    return (iEast, fracE)

class OLC_Offset:
    def __init__(self, lat1=None, lng1=None, lat2=None, lng2=None, mR_est=None, mN_est=None, mE_est=None):
        gripes = []

        has_est = True
        if mR_est is None:
            has_est = False
        if mN_est is None:
            has_est = False
        if mE_est is None:
            has_est = False
        if not has_est:
            mR_est, mN_est, mE_est = None, None, None

        if len(gripes) == 0:
            if has_est:
                if not isinstance(mR_est, float):
                    gripes.append(f"mR_est={mR_est} must be a floating-point number.")
                if not isinstance(mN_est, float):
                    gripes.append(f"mN_est={mN_est} must be a floating-point number.")
                if not isinstance(mE_est, float):
                    gripes.append(f"mE_est={mE_est} must be a floating-point number.")

        if len(gripes) == 0:
            if not isinstance(lat1, float):
                gripes.append(f"lat1={lat1} must be a floating point number.")
            elif not(OLC_LATITUDE_SOUTH_POLE <= lat1 <= OLC_LATITUDE_NORTH_POLE):
                gripes.append(f"lat1={lat1} is not valid.")

        if len(gripes) == 0:
            if not isinstance(lat2, float):
                gripes.append(f"lat2={lat2} must be a floating point number.")
            elif not(OLC_LATITUDE_SOUTH_POLE <= lat2 <= OLC_LATITUDE_NORTH_POLE):
                gripes.append(f"lat2={lat2} is not valid.")

        if len(gripes) == 0:
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            if not isinstance(lng1, float):
                gripes.append(f"lng1={lng1} must be a floating point number.")
            elif not(OLC_LONGITUDE_DATELINE_WEST <= lng1 <= OLC_LONGITUDE_DATELINE_EAST):
                gripes.append(f"lng1={lng1} is not valid.")

        if len(gripes) == 0:
            if not isinstance(lng2, float):
                gripes.append(f"lng2={lng2} must be a floating point number.")
            elif not(OLC_LONGITUDE_DATELINE_WEST <= lng2 <= OLC_LONGITUDE_DATELINE_EAST):
                gripes.append(f"lng2={lng2} is not valid.")

        if len(gripes) == 0:
            try:
                gdict = Geodesic.WGS84.Inverse(lat1, lng1, lat2, lng2) # use the WGS84 ellipsoid

                # range in meters from latlng1 to latlng2
                #      (rounded to nearest millimeter)
                range_meters_raw = gdict['s12']

                # components of forward azimuth at latlng1
                azi1_rad = np.radians(gdict['azi1'])
                azi12_n = sci_round(np.cos(azi1_rad), 10)
                azi12_e = sci_round(np.sin(azi1_rad), 10)
            except:
                gripes.append(f"failure during Geodesic.WGS84.Inverse({lat1}, {lng1}, {lat2}, {lng2}).")

        if len(gripes) == 0:
            mR = np.round(range_meters_raw, 3)
            mN = np.round(range_meters_raw * azi12_n, 3)  # this is admittedly an estimate
            mE = np.round(range_meters_raw * azi12_e, 3)  # this is admittedly an estimate
            if has_est:
                delta_mR = np.round(mR_est - mR, 3)
                delta_mN = np.round(mN_est - mN, 3)
                delta_mE = np.round(mE_est - mE, 3)
            else:
                delta_mR = None
                delta_mN = None
                delta_mE = None

            self.valid = True
            self.latlng1 = (lat1, lng1)
            self.latlng2 = (lat2, lng2)
            self.mR = mR
            self.delta_mR = delta_mR
            self.mN = mN
            self.delta_mN = delta_mN
            self.mE = mE
            self.delta_mE = delta_mE
            self.azi12_n = azi12_n
            self.azi12_e = azi12_e
        else:
            self.valid = False
            self.latlng1 = (lat1, lng1)
            self.latlng2 = (lat2, lng2)
            self.gripes = gripes

    def __str__(self):
        return f"|OLC_Offset({repr(self.latlng1)},{repr(self.latlng2)})|"

    def __repr__(self):
        s = []
        for k in self.__dict__:
            if k in ['mR', 'delta_mR', 'mN', 'delta_mN', 'mE', 'delta_mE']:
                s.append(f".{k}={repr(self.__dict__[k])}")
        return '|' + ', '.join(s) + '|'

class OLC_Point:
    def __init__(self, latitude=None, longitude=None):
        gripes = []

        if len(gripes) == 0:
            if not isinstance(latitude, float):
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                gripes.append(f"the latitude must be specified.")
            elif not(OLC_LATITUDE_SOUTH_POLE <= latitude <= OLC_LATITUDE_NORTH_POLE):
                gripes.append(f"the latitude {latitude} is not valid.")

        if len(gripes) == 0:
            if not isinstance(longitude, float):
                gripes.append(f"the longitude must be specified.")
            elif not(OLC_LONGITUDE_DATELINE_WEST <= longitude <= OLC_LONGITUDE_DATELINE_EAST):
                gripes.append(f"the longitude {longitude} is not valid.")

        if len(gripes) == 0:
            iN_fN = olc_latitude_to_iNorth_fracN(latitude)
            if iN_fN is None:
                gripes.append(f"failure during olc_latitude_to_iNorth_fracN({latitude}).")
            else:
                iNorth, fracN = iN_fN

        if len(gripes) == 0:
            iE_fE = olc_longitude_to_iEast_fracE(longitude)
            if iE_fE is None:
                gripes.append(f"failure during olc_longitude_to_iEast_fracE({longitude}).")
            else:
                iEast, fracE = iE_fE

        if len(gripes) == 0:
            code_bedrock = olc_encode_tau((latitude, longitude), OLC_TAU_BEDROCK)
            if code_bedrock is None:
                gripes.append(f"failure during olc_encode_tau(({latitude}, {longitude}), {OLC_TAU_BEDROCK}).")

        if len(gripes) == 0:
            self.valid = True
            self.lat = latitude
            self.lng = longitude
            self.latlng = (latitude, longitude)
            self.uNorth = iNorth + fracN
            self.iNorth = iNorth
            self.fracN = fracN
            self.uEast = iEast + fracE
            self.iEast = iEast
            self.fracE = fracE
            self.code_bedrock = code_bedrock
            self.has_codes = False
        else:
            self.valid = False
            self.latlng = (latitude, longitude)
            self.has_codes = False
            self.gripes = gripes

    def code(self, tau=None, tier=None):
        gripes = []

        this_code = None

        if tier == 'bedrock':
            # process tier-specific request for code_bedrock
            return self.code_bedrock

        if tau == OLC_TAU_BEDROCK:
            # process tau-specific request for code_bedrock
            return self.code_bedrock

        if not self.has_codes:
            # generate this zone's encoding-related information
            valid_taus = [t for t in OLC_TAUs if t <= OLC_TAU_BEDROCK]
            valid_tiers = [OLC_tau_to_tier[t] for t in valid_taus]
            valid_codes = []
            for t in valid_taus:
                try:
                    code_t = olc_encode_tau(self.latlng, t)
                    valid_codes.append(code_t)
                except:
                    gripes.append(f"failure during olc_encode_tau({self.latlng}, {t}).")
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            if len(gripes) == 0:
                tau_to_code = dict(zip(valid_taus, valid_codes))
                tier_to_code = dict(zip(valid_tiers, valid_codes))

                # store this zone's encoding-related information
                #      for possible future use.
                self.has_codes = True
                self.valid_taus = valid_taus
                self.valid_tiers = valid_tiers
                self.valid_codes = valid_codes
                self.tau_to_code = tau_to_code
                self.tier_to_code = tier_to_code
        else:
            valid_taus = self.valid_taus
            valid_tiers = self.valid_tiers
            valid_codes = self.valid_codes
            tau_to_code = self.tau_to_code
            tier_to_code = self.tier_to_code

        if len(gripes) == 0:
            if tau in valid_taus:
                code_tau = tau_to_code[tau]
                if tier in valid_tiers:
                    if code_tau == tier_to_code[tier]:
                        # there is no conflict between tau and tier, so use tau
                        this_code = code_tau
                    else:
                        gripes.append(f"parameters tau={tau} and tier={tier} have conflicting values.")
                else:
                    this_code = code_tau
            else:
                if tier in valid_tiers:
                    this_code = tier_to_code[tier]
                else:
                    gripes.append(f"neither tau={tau} nor tier={tier} is valid.")

        if len(gripes) > 0:
            self.gripes = gripes
        return this_code

    def __str__(self):
        return f"|OLC_Point{repr(self.latlng)}|"

    def __repr__(self):
        s = []
        for k in self.__dict__:
            s.append(f".{k}={repr(self.__dict__[k])}")
        return '|' + ', '.join(s) + '|'

class OLC_Zone:
    def __init__(self, code=None, parent=None):
        gripes = []

        if (code is None) or (code == OLC_CODE_PLANET):
            midpoint = (OLC_LATITUDE_EQUATOR, OLC_LONGITUDE_GREENWICH)
            origin = (OLC_LATITUDE_SOUTH_POLE, OLC_LONGITUDE_DATELINE_WEST)
            zone_dict = {}
            zone_dict['parent'] = None
            zone_dict['tau'] = OLC_TAU_PLANET
            zone_dict['tier'] = OLC_TIER_PLANET
            zone_dict['code'] = OLC_CODE_PLANET
            zone_dict['origin'] = OLC_Point(*origin)
            zone_dict['midpoint'] = OLC_Point(*midpoint)
            zone_dict['offset_from_parent'] = None
            zone_dict[OLC_OFFSET_N] =  OLC_Offset(*midpoint, OLC_LATITUDE_NORTH_POLE, OLC_LONGITUDE_GREENWICH)
            zone_dict[OLC_OFFSET_NE] = OLC_Offset(*midpoint, OLC_LATITUDE_NORTH_POLE, OLC_LONGITUDE_DATELINE_EAST)
            zone_dict[OLC_OFFSET_E] =  OLC_Offset(*midpoint, OLC_LATITUDE_EQUATOR, OLC_LONGITUDE_DATELINE_EAST)
            zone_dict[OLC_OFFSET_SE] = OLC_Offset(*midpoint, OLC_LATITUDE_SOUTH_POLE, OLC_LONGITUDE_DATELINE_EAST)
            zone_dict[OLC_OFFSET_S] =  OLC_Offset(*midpoint, OLC_LATITUDE_SOUTH_POLE, OLC_LONGITUDE_GREENWICH)
            zone_dict[OLC_OFFSET_SW] = OLC_Offset(*midpoint, OLC_LATITUDE_SOUTH_POLE, OLC_LONGITUDE_DATELINE_WEST)
            zone_dict[OLC_OFFSET_W] =  OLC_Offset(*midpoint, OLC_LATITUDE_EQUATOR, OLC_LONGITUDE_DATELINE_WEST)
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            zone_dict[OLC_OFFSET_NW] = OLC_Offset(*midpoint, OLC_LATITUDE_NORTH_POLE, OLC_LONGITUDE_DATELINE_WEST)
            this_offsets = [zone_dict[offset] for offset in OLC_OFFSETs]
        else:
            if isinstance(parent, type(self)):
                this_parent = parent
            else:
                gripes.append(f"a parent zone was not specified.")

            if len(gripes) == 0:
                try:
                    codeArea = olc.decode(code)
                    this_code = code
                except:
                    gripes.append(f"failed to decode OLC code {repr(code)}.")

            if len(gripes) == 0:
                this_codeLen = codeArea.codeLength
                if not this_codeLen in OLC_CODELENs[1:]:
                    gripes.append(f"the derived code length {this_codeLen} of OLC code {repr(this_code)} is not valid.")

            if len(gripes) == 0:
                try:
                    this_tau = OLC_codeLen_to_tau[this_codeLen]
                except:
                    gripes.append(f"failed to evaluate OLC_codeLen_to_tau[{this_codeLen}].")

            if len(gripes) == 0:
                try:
                    this_tier = OLC_tau_to_tier[this_tau]
                except:
                    gripes.append(f"failed to evaluate OLC_tau_to_tier[{this_tau}].")

            if len(gripes) == 0:
                lat_hi = round(codeArea.latitudeHi, 12)
                lat_md = round(codeArea.latitudeCenter, 12)
                lat_lo = round(codeArea.latitudeLo, 12)
                lng_hi = round(codeArea.longitudeHi, 12)
                lng_md = round(codeArea.longitudeCenter, 12)
                lng_lo = round(codeArea.longitudeLo, 12)
                lat_parent = this_parent.midpoint.lat
                lng_parent = this_parent.midpoint.lng
                zone_dict = {}
                zone_dict['parent'] = this_parent
                zone_dict['tau'] = this_tau
                zone_dict['tier'] = this_tier
                zone_dict['code'] = this_code
                zone_dict['origin'] = OLC_Point(lat_lo, lng_lo)
                zone_dict['midpoint'] = OLC_Point(lat_md, lng_md)
                zone_dict['offset_from_parent'] = OLC_Offset(lat_parent, lng_parent, lat_md, lng_md)
                zone_dict[OLC_OFFSET_N] =  OLC_Offset(lat_md, lng_md, lat_hi, lng_md)
                zone_dict[OLC_OFFSET_NE] = OLC_Offset(lat_md, lng_md, lat_hi, lng_hi)
                zone_dict[OLC_OFFSET_E] =  OLC_Offset(lat_md, lng_md, lat_md, lng_hi)
                zone_dict[OLC_OFFSET_SE] = OLC_Offset(lat_md, lng_md, lat_lo, lng_hi)
                zone_dict[OLC_OFFSET_S] =  OLC_Offset(lat_md, lng_md, lat_lo, lng_md)
                zone_dict[OLC_OFFSET_SW] = OLC_Offset(lat_md, lng_md, lat_lo, lng_lo)
                zone_dict[OLC_OFFSET_W] =  OLC_Offset(lat_md, lng_md, lat_md, lng_lo)
                zone_dict[OLC_OFFSET_NW] = OLC_Offset(lat_md, lng_md, lat_hi, lng_lo)
                this_offsets = [zone_dict[offset] for offset in OLC_DIAGONAL_OFFSETs]

        if len(gripes) == 0:
            this_tolerances = [zone_offset.mR for zone_offset in this_offsets]
            this_tolerance = np.round(np.max(this_tolerances), 3)
            zone_dict['tolerance'] = this_tolerance

        if len(gripes) == 0:
            self.valid = True
            self.is_pending = True
            self.__dict__.update(zone_dict)
            self.children = {}
        else:
            self.valid = False
            self.gripes = gripes
```

```
504
505     def __str__(self):
506         return f"|OLC_Zone({repr(self.code)})|"
507
508     def __repr__(self):
509         s = []
510         for k in self.__dict__:
511             if k == "parent":
512                 s.append(f".{k}={str(self.parent)}")
513             elif k == "children":
514                 child_zones = ", ".join([str(c_z) for c_z in self.children.values()])
515                 s.append(f".{k}=[{child_zones}]")
516             else:
517                 s.append(f".{k}={repr(self.__dict__[k])}")
518         return '|' + ', '.join(s) + '|'
519
520     def event_add(self, event_index, event_latlng):
521         gripes = []
522         if self.tau == OLC_TAU_BEDROCK:
523             event_lat, event_lng = event_latlng
524             try:
525                 self.j_index.append(event_index)
526             except:
527                 self.j_index = [event_index]
528             try:
529                 self.j_lat.append(event_lat)
530             except:
531                 self.j_lat = [event_lat]
532             try:
533                 self.j_lng.append(event_lng)
534             except:
535                 self.j_lng = [event_lng]
536         else:
537             child_code = olc_encode_tau(event_latlng, self.tau + 1)
538             child_zone = None
539             try:
540                 child_zone = self.children[child_code]
541             except:
542                 pass
543
544             if not isinstance(child_zone, type(self)):
545                 child_zone = OLC_Zone(code=child_code, parent=self)
546                 try:
547                     self.children[child_code] = child_zone
548                 except:
549                     gripes.append(f"failed to assign self.children[{repr(child_code)}] = {str(child_zone)}).")
550
551             if not isinstance(child_zone, type(self)):
552                 gripes.append(f"child_zone is not an instance of type {type(self)}.")
553
554             if len(gripes) == 0:
555                 child_zone.event_add(event_index, event_latlng)
556
557             if len(gripes) > 0:
558                 for gripe in gripes:
559                     print(gripe)
560         return
561
562     def flip_to_pending(self):
563         num_flips = 0
564
565         child_zones = list(self.children.values())
566         for zone_c in child_zones:
567             num_flips += zone_c.flip_to_pending()
568
569         if not self.is_pending:
570             self.is_pending = True
571             num_flips += 1
572
573         return num_flips
574
575     def search(self, Q, K, slate_previous=None, mR_est=None, mN_est=None, mE_est=None):
```

```
576
577         def search_radius(slate, N):
578             try:
579                 # if slate already contains a number iNum
580                 # of nearest-neighbor candidates, the distance
581                 # to the iNum^th neighbor (SO FAR) will be
582                 # the NEW (working) search radius.
583                 radius = slate[N - 1][0]
584             except:
585                 # slate does NOT yet contain the needed minimum
586                 #     number K of nearest-neighbor candidates.
587                 # let the search radius be implausibly large
588                 radius = OLC_EARTH_CIRCUMFERENCE
589             return radius
590
591         def slate_display(slate, comment):
592             if len(slate) == 0:
593                 print(f"{comment} is empty.")
594                 print()
595             else:
596                 print(f"{comment} is as follows:")
597                 nomDossiers = [nomDoss_j for R_j, code_j, nomDoss_j in slate]
598                 for i, nomDoss in enumerate(nomDossiers):
599                     print(f"i={i}: {repr(nomDoss)}")
600                 print()
601             return
602
603         if self.tau == OLC_TAU_PLANET:
604             # the current zone represents a planet.
605             #      reset the "is_pending" flags to True
606             #      for the current zone and all its subzones
607             num_flip = self.flip_to_pending()
608
609             #      start with a "clean" slate of nearest neighbors
610             slate_previous = []
611         else:
612             if not self.is_pending:
613                 # Nothing to see here.  Keep moving.
614                 return slate_previous
615
616         slate_b = slate_previous
617
618         gripes = []
619
620         tau_b = self.tau
621         tier_b = self.tier
622         code_b = self.code
623         theta_b = self.tolerance
624
625         if tau_b == OLC_TAU_BEDROCK:
626             # zone_b exists within the BEDROCK tier
627             # therefore zone_b cannot have child zones
628
629             if code_b == Q.code_bedrock:
630                 # Bedrock-tier zone_b CONTAINS point Q
631                 #      we purposely EXCLUDE zone_b from placement
632                 #      onto (its own) K-nearest-neighbors list.
633                 self.is_pending = False
634                 return slate_b
635             else:
636                 # Bedrock-tier zone_b DOES NOT CONTAIN point Q
637                 offset_Qb = OLC_Offset(*Q.latlng, *self.midpoint.latlng, mR_est, mN_est, mE_est)
638                 self.offset_Qb = offset_Qb
639
640                 mN_Qb = offset_Qb.mN
641                 delta_mN_Qb = offset_Qb.delta_mN
642                 mE_Qb = offset_Qb.mE
643                 delta_mE_Qb = offset_Qb.delta_mE
644                 mR_Qb = offset_Qb.mR
645                 delta_mR_Qb = offset_Qb.delta_mR
646
647                 R_Qb_min = np.round(np.max([0, np.subtract(mR_Qb, theta_b)]), 3)
```

```
                R_Qb_max = np.round(mR_Qb + theta_b, 3)

                if R_Qb_min > search_radius(slate_b, K):
                    # zone_b lies completely OUTSIDE the current search radius.
                    #      Ignore it.
                    self.is_pending = False
                    return slate_b
                else:
                    # parts of zone_b lie WITHIN the prescribed search radius.
                    #      Regard zone_b as a potential member of the
                    #      K-nearest-neighbors list.
                    nomDoss = {}
                    nomDoss['code'] = code_b
                    nomDoss['event_indices'] = self.j_index
                    nomDoss['R'] = mR_Qb
                    nomDoss['dR'] = delta_mR_Qb
                    nomDoss['R_min'] = R_Qb_min
                    nomDoss['R_max'] = R_Qb_max

                    nominee = (mR_Qb, code_b, nomDoss)
                    slate_b = list(sorted([*slate_b, nominee]))[0:K]
                    self.is_pending = False
                    return slate_b

        # At this point, we know that zone_b is ABOVE the bedrock tier

        # Check whether zone_b has any child zones
        child_codes_raw = list(self.children.keys())
        if len(child_codes_raw) == 0:
            # zone_b has no child zones
            self.is_pending = False
            return slate_b

        # calculate the geodesic distance from Point Q to the
        # midpoint of zone_b (this gets used in the estimation of
        # the distance from Point Q to the center of child zone c, later)
        offset_Qb = OLC_Offset(*Q.latlng, *self.midpoint.latlng, mR_est, mN_est, mE_est)
        self.offset_Qb = offset_Qb
        mN_Qb = offset_Qb.mN
        mE_Qb = offset_Qb.mE

        # Check whether zone_b has a child zone that CONTAINS point Q
        code_Qc = Q.code(tau_b + 1)
        if code_Qc in child_codes_raw:
            # zone_b has a child zone that CONTAINS point Q.
            # search that child zone.
            zone_c = self.children[code_Qc]
            tier_c = zone_c.tier
            mN_bc = zone_c.offset_from_parent.mN
            mE_bc = zone_c.offset_from_parent.mE
            mN_Qc_est = np.round(mN_Qb + mN_bc, 3)
            mE_Qc_est = np.round(mE_Qb + mE_bc, 3)
            mR_Qc_est = np.round(np.sqrt(mN_Qc_est**2 + mE_Qc_est**2), 3)
            slate_new = zone_c.search(Q, K, slate_b, mR_Qc_est, mN_Qc_est, mE_Qc_est)
            slate_b = slate_new
            child_codes = [code_c for code_c in child_codes_raw if not code_c == code_Qc]
        else:
            child_codes = child_codes_raw

        if len(child_codes) == 0:
            # we have processed all child codes of interest
            # within zone_b
            self.is_pending = False
            return slate_b

        child_zones = [self.children[code_c] for code_c in child_codes]
        zones_pending = [zone_c for zone_c in child_zones if zone_c.is_pending]
        if len(zones_pending) == 0:
            # zone_b has no PENDING child zones
            self.is_pending = False
            return slate_b

```

```
        # At this point, zone_b still has one or more PENDING child zones

        # Estimation phase:  calculate ESTIMATED geodesic distance between Q
        # and the midpoint of each child zone, zone_c
        docket_raw = []
        for zone_c in zones_pending:
            theta_c = zone_c.tolerance
            mN_bc = zone_c.offset_from_parent.mN
            mE_bc = zone_c.offset_from_parent.mE
            mN_Qc_est = np.round(mN_Qb + mN_bc, 3)
            mE_Qc_est = np.round(mE_Qb + mE_bc, 3)
            mR_Qc_est = np.round(np.sqrt(mN_Qc_est**2 + mE_Qc_est**2), 3)
            R_Qc_min = np.round(np.max([0, np.subtract(mR_Qc_est, theta_c)]), 3)
            R_Qc_max = np.round(mR_Qc_est + theta_c, 3)
            if R_Qc_min > search_radius(slate_b, K):
                # all parts of zone_c are completely OUTSIDE
                # the prescribed search radius
                # Exclude this child zone from the "docket"
                zone_c.is_pending = False
            else:
                # some parts of zone_c lie WITHIN
                # the prescribed search radius
                # put zone_c on the "docket"
                task_c = (mR_Qc_est, mN_Qc_est, mE_Qc_est, zone_c)
                docket_raw.append(task_c)

        if len(docket_raw) == 0:
            # None of the child zones warranted a detailed search
            self.is_pending = False
            return slate_b

        docket = sorted(docket_raw)
        for mR_Qc_est, mN_Qc_est, mE_Qc_est, zone_c in docket:
            slate_c = zone_c.search(Q, K, slate_b, mR_Qc_est, mN_Qc_est, mE_Qc_est)
            slate_b = slate_c

        self.is_pending = False

        return slate_b

def olc_K_nearest_neighbors(events_index, events_latlng, K):

    planet = OLC_Zone(OLC_CODE_PLANET)
    print("AFTER __init__...")
    print(repr(planet))
    print()

    num_events = len(events_index)

    events_i_latlng = list(zip(events_i, events_latlng))

    for i, latlng in events_i_latlng:
        planet.event_add(event_index=i, event_latlng=latlng)
    print()

    print("AFTER ADDING ALL EVENTS...")
    print(repr(planet))
    print()

    events_KNN = []
    print("======================================================")
    print(f"STARTED KNN EVALUATION AT {datetime.now()}")
    print()
    print("======================================================")
    for i, Q_latlng in events_i_latlng:
        write_line = False
        if i == 0:
            write_line = True
        if i == num_events - 1:
            write_line = True
        if i % 50 == 0:
            write_line = True
```

```
792
793         if write_line:
794             print(f"event_i={i}, time={datetime.now()}")
795         Q_i = OLC_Point(*Q_latlng)
796         slate_i = planet.search(Q_i, K)
797         neighbor_eventIndices_i = []
798         for R_ij, code_ij, nomDoss_ij in slate_i:
799             indices_ij = nomDoss_ij['event_indices']
800             for neighbor_eventIndex in indices_ij:
801                 neighbor_eventIndices_i.append(neighbor_eventIndex)
802         KNN_i = neighbor_eventIndices_i[0:K]
803         events_KNN.append(KNN_i)
804
805     return events_KNN
806
807 test_the_functions = False
808 if test_the_functions:
809     A_latlng = (47.5111, -122.2571) # bedrock code = '84VVGP6V+C5'
810     B_latlng = (47.7210, -122.319)  # bedrock code = '84VVPMCJ+CC'
811     P_latlng = (47.7379, -122.233)  # bedrock code = '84VVPQQ8+5R
812     Q_latlng = (47.5208, -122.393)  # bedrock code = '84VVGJC4+8R'
813
814     point_A = OLC_Point(*A_latlng)
815     print("point_A after __init__=")
816     print(repr(point_A))
817     print()
818
819     point_B = OLC_Point(*B_latlng)
820     print("point_B after __init__=")
821     print(repr(point_B))
822     print()
823
824     point_P = OLC_Point(*P_latlng)
825     print("point_P after __init__=")
826     print(repr(point_P))
827     print()
828
829     point_Q = OLC_Point(*Q_latlng)
830     print("point_Q after __init__=")
831     print(repr(point_Q))
832     print()
833
834     Q_code_bedrock = point_Q.code(tier="bedrock")
835     print(f"Q_code_bedrock={repr(Q_code_bedrock)}")
836     print()
837
838     Q_code_holler = point_Q.code(tier="holler")
839     print(f"Q_code_holler={repr(Q_code_holler)}")
840     print()
841
842     print("after point_Q.code(tier='holler') was invoked, point_Q=")
843     print(repr(point_Q))
844     print()
845
846     offset_PQ = OLC_Offset(*P_latlng, *Q_latlng)
847     print("offset_PQ =")
848     print(repr(offset_PQ))
849     print()
850
851     # Create an empty instance OLC_Zone() called "planet"
852     # this will be the "planet Zone"
853     planet = OLC_Zone()
854     print("AFTER __init__...")
855     print(repr(planet))
856     print()
857
858     # Add some events to the "planet zone"
859     num_events = 4
860     event_i = list(range(num_events))
861     event_latlng = [A_latlng, B_latlng, P_latlng, Q_latlng]
862     event_i_latlng = list(zip(event_i,event_latlng))
863     for i, latlng in event_i_latlng:
```

```
        planet.event_add(event_index=i, event_latlng=latlng)
    print(f"AFTER ADDING num_events={num_events}...")
    print(repr(planet))
    print()


    print("code_to_zone dictionary =")
    code_to_zone = olc_add_zone_to_archive(planet)
    display(list(code_to_zone.keys())[0:100])

print("Please proceed to next cell.")
```

```
Please proceed to next cell.
```

In [3]:

```
# ======================================================
#   IMPORT DATA
#
#   Imports data from either the preferred csv file,
#        or from the alternate csv file.
#
# Michael Collins, Flatiron School
# 2020-10-28_0526_MDT
# ======================================================

GLOBAL_ROW = 0
GLOBAL_ROW_LAST = 4

def housing_convert_view(v_str):
    v_value = int(0)
    try:
        v_numeric = pd.to_numeric(v_str, errors='raise')
        view_nonzero = [1, 2, 3, 4]
        if v_numeric in view_nonzero:
            v_value = int(v_numeric)
    except:
        pass
    return v_value

def housing_convert_waterfront(v_str):
    v_value = int(0)
    try:
        v_numeric = pd.to_numeric(v_str, errors='raise')
        if v_numeric > 0:
            v_value = int(v_numeric)
    except:
        pass
    return v_value

def housing_convert_yr_renovated(v_str):
    v_value = int(0)
    try:
        v_numeric = pd.to_numeric(v_str, errors='raise')
        year_first = 1900
        year_last = datetime.now().year
        years_nonzero = list(range(year_first, year_last + 1))
        if v_numeric in years_nonzero:
            v_value = int(v_numeric)
    except:
        pass
    return v_value

def housing_convert_sfBasement(v_str):
    v_value = int(0)
    try:
        v_numeric = pd.to_numeric(v_str, errors='raise')
        if v_numeric > 0:
            v_value = int(v_numeric)
    except:
        pass
    return v_value

housing_columns_raw =  ['id',            # included in housing_dtype
                        'date',          # included in housing_parse_dates
                        'price',
                        'bedrooms',
                        'bathrooms',
                        'sqft_living',
                        'sqft_lot',
                        'floors',
                        'waterfront',    # uses housing_convert_waterfront
                        'view',          # uses housing_convert_view
                        'condition',
                        'grade',
                        'sqft_above',
                        'sqft_basement', # uses housing_convert_sfBasement
```

```
                      'yr_built',
                      'yr_renovated',  # uses housing_convert_yr_renovated
                      'zipcode',
                      'lat',
                      'long',
                      'sqft_living15',
                      'sqft_lot15']
housing_dtype = {'id':str}
housing_parse_dates = ['date']
housing_converters = {'view':housing_convert_view,
                      'waterfront':housing_convert_waterfront,
                      'yr_renovated':housing_convert_yr_renovated,
                      'sqft_basement':housing_convert_sfBasement}

csv_folder = './data/'
csv_prefix_preferred = 'kc_house_data_KNN'
csv_prefix_alternate = 'kc_house_data'
csv_suffix = '.csv'
csvPath_preferred = csv_folder + csv_prefix_preferred + csv_suffix
csvPath_alternate = csv_folder + csv_prefix_alternate + csv_suffix

df_raw = None

if not isinstance(df_raw, pd.DataFrame):
    print(f"Attempting to import data from csv file {repr(csvPath_preferred)}...")
    try:
        GLOBAL_ROW = 0
        df_raw = pd.read_csv(csvPath_preferred,
                             converters=housing_converters,
                             parse_dates=housing_parse_dates,
                             dtype=housing_dtype
                            ).astype({'yr_renovated':int})
        print(f"     Imported data from csv file {repr(csvPath_preferred)}.\n")
    except:
        print(f"Failed to import data from csv file {repr(csvPath_preferred)}.\n")

if not isinstance(df_raw, pd.DataFrame):
    print(f"Attempting to import FILTERED data from csv file {repr(csvPath_alternate)}...")
    try:
        GLOBAL_ROW = 0
        df_raw = pd.read_csv(csvPath_alternate,
                             converters=housing_converters,
                             parse_dates=housing_parse_dates,
                             dtype=housing_dtype
                            ).astype({'yr_renovated':int})
        print(f"     Imported FILTERED data from csv file {repr(csvPath_preferred)}.\n")
    except:
        print(f"Failed to import FILTERED data from csv file {repr(csvPath_alternate)}.\n")

if not isinstance(df_raw, pd.DataFrame):
    print(f"Attempting to import UNFILTERED data from csv file {repr(csvPath_alternate)}...")
    try:
        df_raw = pd.read_csv(csvPath_alternate)
        print(f"     Imported UNFILTERED data from csv file {repr(csvPath_alternate)}.\n")
    except:
        print(f"Failed to import UNFILTERED data from csv file {repr(csvPath_alternate)}.\n")

if not isinstance(df_raw, pd.DataFrame):
    print("Unable to continue without data.\n")
    assert False

print("==================== df_raw COLUMNS ======================")
columns_df_raw = list(df_raw.columns)
print(repr(columns_df_raw))

show_dfRaw_value_counts = True
if show_dfRaw_value_counts:
    print("==================== df_raw Value Counts ======================")
    columns_showVC = ['waterfront', 'view', 'grade', 'yr_built', 'yr_renovated', 'zipcode']
    print(f"for columns = {repr(columns_showVC)}\n")
    for c in columns_showVC:
        print(f"VALUE COUNTS for column = {repr(c)}:")
```

```
        print(df_raw[c].value_counts())
        print()
```

```
df = df_raw.copy()
print("==================== df (original working copy) ======================")
display(df)
print()
```

```
col_lat = 'lat'
col_long = 'long'
col_price = 'price'
col_yr_built = 'yr_built'
col_yr_renovated = 'yr_renovated'
col_bedrooms = 'bedrooms'
col_bathrooms = 'bathrooms'
col_floors = 'floors'
col_waterfront = 'waterfront'
col_view = 'view'
col_condition = 'condition'
col_grade = 'grade'
col_sfLiving = 'sqft_living'
col_sfAbove = 'sqft_above'
col_sfBasement = 'sqft_basement'
col_sfYard = 'sqft_lot'

events_i = list(df.index.values)
num_events = len(events_i)
events_lat = [round(lat, 3) for lat in df[col_lat].to_list()]
events_lng = [round(lng, 3) for lng in df[col_long].to_list()]
events_latlng = list(zip(events_lat, events_lng))
events_price = [p for p in df[col_price].to_list()]
events_bedrooms = [b for b in df[col_bedrooms].to_list()]
events_view = [v for v in df[col_view].to_list()]
events_bathrooms = [b for b in df[col_bathrooms].to_list()]
events_grade = [g for g in df[col_grade].to_list()]
events_yr_built = [y for y in df[col_yr_built].to_list()]
events_yr_renovated = [y for y in df[col_yr_renovated].to_list()]
events_sfLiving = [sf for sf in df[col_sfLiving].to_list()]
events_sfAbove = [sf for sf in df[col_sfAbove].to_list()]
events_sfLiving_sfAbove = list(zip(events_sfLiving, events_sfAbove))
events_i_sfLiving_sfAbove = list(zip(events_i, events_sfLiving, events_sfAbove))
```

```
# The quanta_**** are lists of the unique values that appear
# in the cleaned-up versions of selected columns
quanta_bedrooms = ['1', '2', '3', '4', '5', '6', '7', '8', '9', '10', '11', '33']
quanta_bathrooms = ['0.5', '0.75', '1.0', '1.25', '1.5', '1.75', '2.0', '2.25',
                    '2.5', '2.75', '3.0', '3.25', '3.5', '3.75', '4.0', '4.25',
                    '4.5', '4.75', '5.0', '5.25', '5.5', '5.75', '6.0', '6.25',
                    '6.5', '6.75', '7.5', '7.75', '8.0']
quanta_floors = ['1.0', '1.5', '2.0', '2.5', '3.0', '3.5']
quanta_waterfront = ['0', '1']
quanta_view = ['0', '1', '2', '3', '4']
quanta_condition = ['1', '2', '3', '4', '5']
quanta_grade = ['3', '4', '5', '6', '7', '8', '9', '10', '11', '12', '13']

col_metascore = 'metascore'
events_metascore = []
df[col_metascore] = (df[col_bedrooms]*0 +
                     df[col_bathrooms]*0 +
                     df[col_floors]*0 +
                     df[col_waterfront]*0 +
                     df[col_view]*1 +
                     df[col_condition]*1 +
```

```
                    df[col_grade]*1)
events_metascore = list(df[col_metascore])

# Ignore certain outliers
events_i_bedrooms = list(zip(events_i, events_bedrooms))
eventIndices_BEDROOMS_FAIL = [i for i, beds in events_i_bedrooms if beds > 11]
events_i_bathrooms = list(zip(events_i, events_bathrooms))
eventIndices_BATHROOMS_FAIL = [i for i, baths in events_i_bathrooms if baths < 0.75]


eventIndices_ignore1 = [264, 1166, 1761, 3950, 4365, 4577, 4907, 6096,
                        6825, 8149, 8537, 11544, 14813, 14821, 16404, 16556,
                        17138, 18212, 18261, 18352, 19089, 19173, 20836, 21185]
eventIndices_ignore2 = [540, 700, 1313, 1784, 1943, 2624, 3488, 4014, 4020, 5068,
                        5084, 5685, 5961, 6396, 6685, 7070, 7245, 8050, 8172, 8270,
                        8597, 9027, 9096, 9309, 9503, 10416, 10527, 10977, 11674,
                        11736, 11859, 12122, 12764, 12993, 13110, 13451, 13616, 13757,
                        13774, 14625, 15025, 15246, 15363, 17460, 18194, 18273, 18833,
                        19002, 19308, 19668, 20138, 20309, 20436, 20519, 20812, 20958,
                        21034, 21356, 21469, 21532, 21560]
eventIndices_ignore3 = []
eventIndices_ignore = list(sorted(eventIndices_ignore1 +
                                  eventIndices_ignore2 +
                                  eventIndices_ignore3 +
                                  eventIndices_BEDROOMS_FAIL +
                                  eventIndices_BATHROOMS_FAIL))

events_valid = [not (i in eventIndices_ignore) for i in events_i]
events_intValid = [int(ev) for ev in events_valid]


col_eventValid = 'eventValid'
df.insert(loc=0, column=col_eventValid, value=events_intValid)

col_eventIndex = 'eventIndex'
df.insert(loc=0, column=col_eventIndex, value=events_i)


# ====================================================
#   Check whether needed CUSTOM data series (columns)
#        are already present in the imported data.
#   If a needed custom series is NOT already present,
#        construct the data for that series, and then
#        ADD that series to the data frame.
# ====================================================

print("looking up building_age...")
print()
col_building_age = 'building_age'
if col_building_age in columns_df_raw:
    events_building_age = df[col_building_age]
else:
    year_now = datetime.now().year
    events_building_age = [int(year_now - yr) for yr in events_yr_built]
    df[col_building_age] = events_building_age

print("looking up interior_age...")
print()
# Number of years since renovation (if yr_renovated is nonzero), otherwise the
#      number of years since original construction
col_interior_age = 'interior_age'
if col_interior_age in columns_df_raw:
    events_interior_age = df[col_interior_age]
else:
    events_yrBldg_yrReno = list(zip(events_yr_built, events_yr_renovated))
    events_i_yrBldg_yrReno = list(zip(events_i, events_yr_built, events_yr_renovated))
    for i, yrBldg, yrReno in events_i_yrBldg_yrReno:
        if not yrReno == 0:
            if yrReno < yrBldg:
                print(f"row {i} of {num_events}: yr_built={yrBldg}, yr_renovated={yrReno}); yr_renovated is not plausible.")
    year_now = datetime.now().year
    events_interior_age = [(int(year_now - yrReno) if yrReno > 0 else int(year_now - yrBldg))
```

```
                           for yrBldg, yrReno in events_yrBldg_yrReno]
    df[col_interior_age] = events_interior_age

print("forcing sfBasement = (sfLiving - sfAbove) ...")
print()
col_sfBasement = 'sqft_basement'
for i, sfLiving, sfAbove in events_i_sfLiving_sfAbove:
    if sfLiving < sfAbove:
        print(f"row {i} of {num_events}: sfLiving={sfLiving}, sfAbove={sfAbove}); sfBasement cannot be negative; using zero")
events_sfBasement = [np.max([0, int(sfLiving - sfAbove)]) for sfLiving, sfAbove in events_sfLiving_sfAbove]
df[col_sfBasement] = events_sfBasement

print("looking up log10_price...")
print()
col_log10_price = 'log10_price'
if col_log10_price in columns_df_raw:
    events_log10_price = df[col_log10_price]
else:
    events_log10_price = [round(np.log10(p), 3) for p in events_price]
    df[col_log10_price] = events_log10_price




def sim_KNN(iEvent, eventIndices, iNum):
    eventIndices_X = [ei for ei in eventIndices if not ei == iEvent]
    indices_drawn = np.random.choice(eventIndices_X, iNum, replace=False)
    return list(indices_drawn)

K_table = 50
print(f"looking up indices of nearest K={K_table} events...")
print()
simulate_KNN = False
if simulate_KNN:
    col_KNN = 'sim_KNN'
else:
    col_KNN = 'KNN'

time_start = datetime.now()
if col_KNN in columns_df_raw:
    print(f"======= FOUND events_KNN information in df_raw ========\n")
    events_KNN = [[int(s) for s in sL[1:-1].split(', ')] for sL in df[col_KNN]]
else:
    if simulate_KNN:
        print(f"=================SIMULATING olc_K_nearest_neighbors(events_i, events_latlng, K={K_table}) ======================\n")
        events_KNN = []
        for i in events_i:
            write_line = False
            if i == 0:
                write_line = True
            if i == num_events - 1:
                write_line = True
            if i % 1000 == 0:
                write_line = True

            if write_line:
                print(f"i={i}, datetime.now()={datetime.now()}")
            KNN_i = sim_KNN(i, events_i, K_table)
            events_KNN.append(KNN_i)
        print(f"=================DONE SIMULATING olc_K_nearest_neighbors(events_i, events_latlng, K={K_table}) ======================\n")
    else:
        print(f"=================CALLING olc_K_nearest_neighbors(events_i, events_latlng, K={K_table}) ======================\n")
        events_KNN = olc_K_nearest_neighbors(events_i, events_latlng, K_table)
        print(f"=================DONE WITH olc_K_nearest_neighbors(events_i, events_latlng, K={K_table}) ======================\n")

    df[col_KNN] = events_KNN



# ============================================================
#   Derive target and features from K-nearest-neighbors lists
# ============================================================
```

```
columns_v =['price',
            'bedrooms',
            'bathrooms',
            'floors',
            'waterfront',
            'view',
            'condition',
            'grade',
            'metascore',
            'sqft_living',
            'sqft_above',
            'sqft_basement',
            'sqft_lot',
            'building_age',
            'interior_age']

K_use = 15
col_price_median = f"{col_price}_median{K_use}"
for col_v in columns_v:

    print(f"Generating new columns for {repr(col_v)} using K={K_use} nearest neighbors...")

    events_v = df[col_v]
    events_v_mean = []
    events_v_median = []
    events_v_diff = []
    events_v_delta = []
    events_v_sigma = []
    events_v_MAD = []
    events_v_zScore = []
    events_v_zed = []
    events_v_phi = []

    for i in events_i:
        if events_valid[i]:
            p_i = events_price[i]
            v_i = events_v[i]
            eventIndices_i = events_KNN[i]
            eventIndices_i_valid = [ei for ei in eventIndices_i if events_valid[ei]][0:K_use]
            p_knn_valid = [events_price[eiv] for eiv in eventIndices_i_valid]
            v_knn_valid = [events_v[eiv] for eiv in eventIndices_i_valid]
            p_mean = np.mean(p_knn_valid)
            p_median = np.median(p_knn_valid)
            p_diff = p_i - p_mean
            v_mean = np.mean(v_knn_valid)
            v_median = np.median(v_knn_valid)
            v_diff = v_i - v_mean
            v_delta = v_i - v_median
            v_sigma = np.std(v_knn_valid)
            v_MAD = MAD(v_knn_valid)

            # Calculate "zScore"
            if v_sigma == 0:
                v_zScore = 0
            else:
                v_zScore = v_diff / v_sigma
                if v_zScore < -5:
                    v_zScore = -5
                if v_zScore > 5:
                    v_zScore = 5

            # Calculate "zed"
            if col_v == col_price:
                # Calculate "zed" for the price
                if p_mean == 0:
                    # This is unlikely, because houses have positive prices
                    v_zed = 0
                else:
                    v_zed = p_diff / p_mean
                    if v_zed < -5:
                        v_zed = -5
```

```
                    if v_zed > 5:
                        v_zed = 5
            else:
                # Calculate "zed" for other quantities
                v_zed = (1 / 100) * v_diff

            # Calculate "phi"
            if p_median == 0:
                v_phi = 0
            else:
                v_phi = (p_median / 100) * (v_delta)
                if v_phi < -5:
                    v_phi = -5
                if v_phi > 5:
                    v_phi = 5

        else:
            v_mean = None
            v_median = None
            v_diff = None
            v_delta = None
            v_sigma = None
            v_MAD = None
            v_zScore = None
            v_zed = None
            v_phi = None

        events_v_mean.append(v_mean)
        events_v_median.append(v_median)
        events_v_diff.append(v_diff)
        events_v_delta.append(v_delta)
        events_v_sigma.append(v_sigma)
        events_v_MAD.append(v_MAD)
        events_v_zScore.append(v_zScore)
        events_v_zed.append(v_zed)
        events_v_phi.append(v_phi)

    df[f"{col_v}_mean{K_use}"] = events_v_mean
    df[f"{col_v}_median{K_use}"] = events_v_median
    df[f"{col_v}_diff{K_use}"] = events_v_diff
    df[f"{col_v}_delta{K_use}"] = events_v_delta
    df[f"{col_v}_sigma{K_use}"] = events_v_sigma
    df[f"{col_v}_MAD{K_use}"] = events_v_MAD
    df[f"{col_v}_zScore{K_use}"] = events_v_zScore
    df[f"{col_v}_zed{K_use}"] = events_v_zed
    df[f"{col_v}_phi{K_use}"] = events_v_phi

print(f"Done generating columns of MEDIANs, DELTAs, MADs, and PHIs using K={K_use} nearest neighbors.\n")


# ======================================================
#   Summarize any changes that were made to the columns
#        that appear in the data frame.
# ======================================================

columns_df = list(df.columns)
print("============== BEGIN Summary of Modifications to Data Frame ==============")
print()
print("__________ all original columns in df_raw:")
print(f"columns_df_raw = " + repr(columns_df_raw))
print()
print("__________ original columns removed from df:")
original_columns_removed_from_df = [cc for cc in columns_df_raw if not cc in columns_df]
print(f"original_columns_removed_from_df = " + repr(original_columns_removed_from_df))
print()
print("__________ original columns preserved in df:")
original_columns_preserved_in_df = [cc for cc in columns_df if cc in columns_df_raw]
print(f"original_columns_preserved_in_df = " + repr(original_columns_preserved_in_df))
print()
print("__________ new columns added to df:")
new_columns_added_to_df = [cc for cc in columns_df if not cc in columns_df_raw]
print(f"new_columns_added_to_df = " + repr(new_columns_added_to_df))
```

```
print()
print("__________ all columns in MODIFIED df:")
print(f"columns_df = " + repr(columns_df))
print()
print("================ END Summary of Modifications to Data Frame ==============")
print()

# ======================================================
#   Auto-save the current data frame to a csv file,
#        regardless of whether it differs from df_raw.
# ======================================================

stamp_now = datetime.now().strftime("%Y-%m-%d_%H%M%S")
print(f"==================== df (as of {stamp_now}) ======================")
display(df)
print()
modified_csv = './data/kc_house_data_modified_' + stamp_now + '.csv'
try:
    df.to_csv(modified_csv, index=False)
    print(f"df (with modified columns) was written to file [{modified_csv}].")
except:
    print(f"FAILED to write df (with modified columns) to file [{modified_csv}].")
print()



# ======================================================
#   Save a subset of the dataframe to a new csv file.
#
# ======================================================

ext_m = "_median"
# ext_d = "_delta"
ext_f = "_zed"
ext_K = K_use
columns_subset =['eventIndex',
                 # 'price',
                 f"price{ext_m}{ext_K}",
                 # f"price{ext_d}{ext_K}",
                 f"price{ext_f}{ext_K}",
                 f"bedrooms{ext_f}{ext_K}",
                 f"bathrooms{ext_f}{ext_K}",
                 f"floors{ext_f}{ext_K}",
                 f"waterfront{ext_f}{ext_K}",
                 f"view{ext_f}{ext_K}",
                 f"condition{ext_f}{ext_K}",
                 f"grade{ext_f}{ext_K}",
                 f"metascore{ext_f}{ext_K}",
                 f"sqft_living{ext_f}{ext_K}",
                 f"sqft_above{ext_f}{ext_K}",
                 f"sqft_basement{ext_f}{ext_K}",
                 f"sqft_lot{ext_f}{ext_K}",
                 f"building_age{ext_f}{ext_K}",
                 f"interior_age{ext_f}{ext_K}"]

df_subset = df[columns_subset].loc[df[col_eventValid] == True]

stamp_now = datetime.now().strftime("%Y-%m-%d_%H%M%S")
print(f"==================== df_subset (as of {stamp_now}) ======================")
display(df_subset)
print()
subset_csv = f"./data/kc_house_data_subset_K={K_use}.csv"
try:
    df_subset.to_csv(subset_csv, index=False)
    print(f"df (with subset columns) was written to file [{subset_csv}].")
except:
    print(f"FAILED to write df (with modified columns) to file [{subset_csv}].")
print()

df_clean = df_subset # df_subset.drop(columns=['price',
                     #              f"price{ext_m}{K_use}",
                     #              #f"price{ext_d}{K_use}"
```

```
                    #             ])

stamp_now = datetime.now().strftime("%Y-%m-%d_%H%M%S")
print(f"==================== df_clean (as of {stamp_now}) ======================")
display(df_clean)
print()
```

2	2	519900.0	-0.617753	-0.013333	-0.012667	-0.007333	0.000000	0.000000	-0.000667	-0.020667	-0.021333	-14.767333	-14.3406
3	3	560000.0	-0.046466	0.010000	0.006500	-0.005667	-0.000667	-0.009333	0.017333	-0.006000	0.002000	-1.240000	-5.0533
4	4	525000.0	0.006215	-0.002000	-0.003000	-0.006000	0.000000	0.000000	-0.000667	-0.000667	-0.001333	-2.500000	-0.9000
...	...	...	...	...	...	...	...	...	...	...	...	...	...
21592	21592	400000.0	-0.122729	0.000000	0.003667	0.008667	0.000000	0.000000	-0.002000	0.006000	0.004000	0.733333	1.4800
21593	21593	340000.0	0.196342	0.006667	0.005500	0.006000	0.000000	0.000000	-0.000667	0.008000	0.007333	5.526667	7.3866
21594	21594	387000.0	-0.014780	-0.006667	-0.012167	0.001333	0.000000	0.000000	-0.001333	-0.000667	-0.002000	-3.500000	-1.8933
21595	21595	387000.0	-0.205077	-0.002667	-0.001333	0.000000	0.000000	-0.001333	0.000000	0.000667	-0.000667	-4.320000	-1.7733
21596	21596	387000.0	-0.203692	-0.006667	-0.012167	0.001333	0.000000	0.000000	-0.001333	-0.000667	-0.002000	-3.500000	-1.8933

21507 rows × 17 columns

In [4]:

```
# ======================================================
#       Ancillary functions related to OLS
#
# Michael Collins, Flatiron School
# 2020-10-30_0639_MDT
#
# ======================================================

def plot_corr(df):
    corr = df.corr().abs()
    plt.figure(figsize=(8, 5))
    sns.heatmap(corr, fmt='0.2g', annot=True, cmap=sns.color_palette('Blues'))
    plt.show()


# VIF test is a great test for multicollinearity
def calculate_vif(df, target_col, show_res=False):
    x = df.drop(columns=[target_col])
    y = df[target_col]
    ols = sm.OLS(y, x).fit()
    if show_res:
        display(ols.summary())
    vif = 1 / (1 - ols.rsquared)
    return vif

print("Please proceed to the next cell.")
```

```
Please proceed to the next cell.
```

In [5]:

```
# ====================================================
#       Selection of Features to Include in OLS
#
# Michael Collins, Flatiron School
# 2020-10-30_0639_MDT
#
# ====================================================

stamp_now = datetime.now().strftime("%Y-%m-%d_%H%M%S")
print(f"==================== df_clean (as of {stamp_now}) ======================")
display(df_clean)
print()

ext_f = "_zed"
ext_K = K_use
cols_every = list(df_clean.columns)
#       Features that are commented out, below,
#       are excluded from consideration
cols_feature = [
    f"bedrooms{ext_f}{ext_K}",
    f"bathrooms{ext_f}{ext_K}",
    f"floors{ext_f}{ext_K}",
    f"waterfront{ext_f}{ext_K}",
    # f"view{ext_f}{ext_K}",
    # f"condition{ext_f}{ext_K}",
    # f"grade{ext_f}{ext_K}",
    f"metascore{ext_f}{ext_K}",
    f"sqft_living{ext_f}{ext_K}",
    # f"sqft_above{ext_f}{ext_K}",
    # f"sqft_basement{ext_f}{ext_K}",
    # f"sqft_lot{ext_f}{ext_K}",
    f"building_age{ext_f}{ext_K}",
    # f"interior_age{ext_f}{ext_K}"
    ]
cols_non_feature = [c for c in cols_every if not c in cols_feature]
col_target = f"price{ext_f}{ext_K}"

print(f"================ cols_every ==================")
print(f"cols_every = {repr(cols_every)}\n")
print(f"============== cols_feature ===============")
print(f"cols_feature = {repr(cols_feature)}\n")
print(f"============== cols_non_feature ===============")
print(f"cols_non_feature = {repr(cols_non_feature)}\n")
print(f"============== col_target ===============")
print(f"col_target = {repr(col_target)}\n")
```

```
==================== df_clean (as of 2020-10-31_083203) ======================
```

	eventIndex	price_median15	price_zed15	bedrooms_zed15	bathrooms_zed15	floors_zed15	waterfront_zed15	view_zed15	condition_zed15	grade_zed15	metascore_zed15	sqft_living_zed15	sqft_above_zed
0	0	400000.0	-0.420485	-0.009333	-0.007667	-0.005000	0.000000	-0.008000	-0.006667	-0.001333	-0.016000	-8.614667	-3.8280
1	1	402000.0	0.388877	0.001333	0.008167	0.006667	0.000000	0.000000	-0.006667	-0.001333	-0.008000	11.451333	9.3480
2	2	519900.0	-0.617753	-0.013333	-0.012667	-0.007333	0.000000	0.000000	-0.000667	-0.020667	-0.021333	-14.767333	-14.3406
3	3	560000.0	-0.046466	0.010000	0.006500	-0.005667	-0.000667	-0.009333	0.017333	-0.006000	0.002000	-1.240000	-5.0533
4	4	525000.0	0.006215	-0.002000	-0.003000	-0.006000	0.000000	0.000000	-0.000667	-0.000667	-0.001333	-2.500000	-0.9000
...	...	...	...	...	...	...	...	...	...	...	...	...	
21592	21592	400000.0	-0.122729	0.000000	0.003667	0.008667	0.000000	0.000000	-0.002000	0.006000	0.004000	0.733333	1.4800
21593	21593	340000.0	0.196342	0.006667	0.005500	0.006000	0.000000	0.000000	-0.000667	0.008000	0.007333	5.526667	7.3866
21594	21594	387000.0	-0.014780	-0.006667	-0.012167	0.001333	0.000000	0.000000	-0.001333	-0.000667	-0.002000	-3.500000	-1.8933
21595	21595	387000.0	-0.205077	-0.002667	-0.001333	0.000000	0.000000	-0.001333	0.000000	0.000667	-0.000667	-4.320000	-1.7733
21596	21596	387000.0	-0.203692	-0.006667	-0.012167	0.001333	0.000000	0.000000	-0.001333	-0.000667	-0.002000	-3.500000	-1.8933

21507 rows × 17 columns

```
================ cols_every ==================
cols_every = ['eventIndex', 'price_median15', 'price_zed15', 'bedrooms_zed15', 'bathrooms_zed15', 'floors_zed15', 'waterfront_zed15', 'view_zed15', 'condition_zed15', 'grad
d15', 'sqft_living_zed15', 'sqft_above_zed15', 'sqft_basement_zed15', 'sqft_lot_zed15', 'building_age_zed15', 'interior_age_zed15']

============== cols_feature ===============
cols_feature = ['bedrooms_zed15', 'bathrooms_zed15', 'floors_zed15', 'waterfront_zed15', 'metascore_zed15', 'sqft_living_zed15', 'building_age_zed15']

============== cols_non_feature ===============
cols_non_feature = ['eventIndex', 'price_median15', 'price_zed15', 'view_zed15', 'condition_zed15', 'grade_zed15', 'sqft_above_zed15', 'sqft_basement_zed15', 'sqft_lot_zed1
5']

============== col_target ===============
col_target = 'price_zed15'
```

In [6]:

```
df_features = df_clean.drop(columns=cols_non_feature)
stamp_now = datetime.now().strftime("%Y-%m-%d_%H%M%S")
print(f"==================== df_features (as of {stamp_now}) ======================")
display(df_features)
print()


# lets find some features based on their correlation scores

columns_correlations = []
columns_non_numeric = []

for col_c in list(df_features.columns):
    try:
        corr = np.abs(df_features[col_c].corr(df_clean[col_target]))
        t = (col_c, corr)
        columns_correlations.append(t)
    except:
        columns_non_numeric.append(col_c)

# let's get all columns with correlation above 0.20

correlated_features_above_point2 = [col_c for col_c, corr in columns_correlations if corr >= 0.20]
print(f"correlated_features_above_point2 =")
print(correlated_features_above_point2)
print()

whole_space = correlated_features_above_point2
whole_space.append(col_target)

correlated_df = df_clean[whole_space]

correlated_df.head()
```

```
==================== df_features (as of 2020-10-31_083203) ======================
```

	bedrooms_zed15	bathrooms_zed15	floors_zed15	waterfront_zed15	metascore_zed15	sqft_living_zed15	building_age_zed15
0	-0.009333	-0.007667	-0.005000	0.000000	-0.016000	-8.614667	-0.160667
1	0.001333	0.008167	0.006667	0.000000	-0.008000	11.451333	0.058667
2	-0.013333	-0.012667	-0.007333	0.000000	-0.021333	-14.767333	0.579333
3	0.010000	0.006500	-0.005667	-0.000667	0.002000	-1.240000	0.050667
4	-0.002000	-0.003000	-0.006000	0.000000	-0.001333	-2.500000	-0.010000
...	...	...	...	...	...	...	...
21592	0.000000	0.003667	0.008667	0.000000	0.004000	0.733333	-0.286667
21593	0.006667	0.005500	0.006000	0.000000	0.007333	5.526667	-0.298000
21594	-0.006667	-0.012167	0.001333	0.000000	-0.002000	-3.500000	-0.351333
21595	-0.002667	-0.001333	0.000000	0.000000	-0.000667	-4.320000	0.004667
21596	-0.006667	-0.012167	0.001333	0.000000	-0.002000	-3.500000	-0.341333

21507 rows × 7 columns

```
correlated_features_above_point2 =
['bedrooms_zed15', 'bathrooms_zed15', 'floors_zed15', 'waterfront_zed15', 'metascore_zed15', 'sqft_living_zed15', 'building_age_zed15']
```

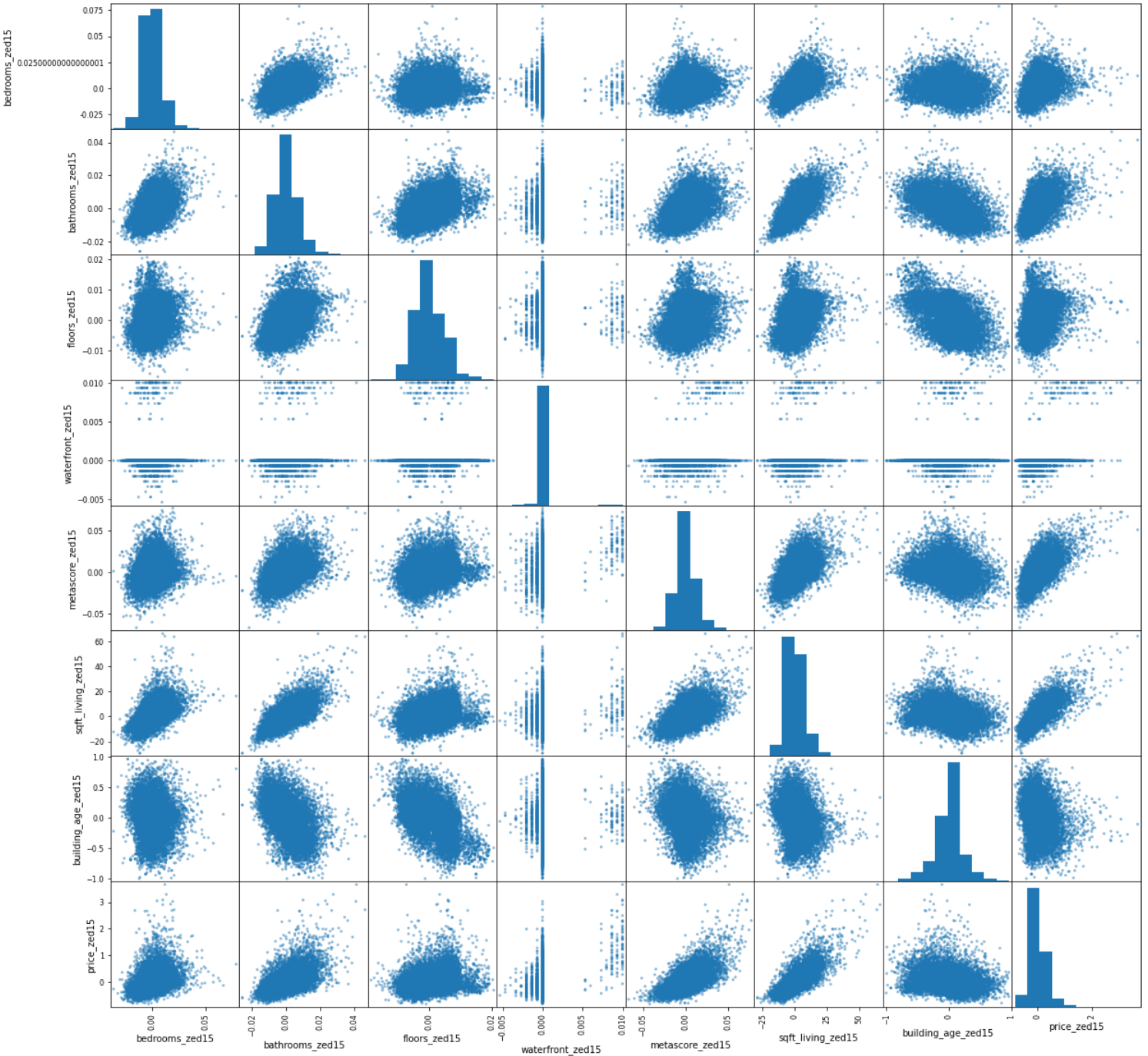
Out[6]:

	bedrooms_zed15	bathrooms_zed15	floors_zed15	waterfront_zed15	metascore_zed15	sqft_living_zed15	building_age_zed15	price_zed15
0	-0.009333	-0.007667	-0.005000	0.000000	-0.016000	-8.614667	-0.160667	-0.420485
1	0.001333	0.008167	0.006667	0.000000	-0.008000	11.451333	0.058667	0.388877
2	-0.013333	-0.012667	-0.007333	0.000000	-0.021333	-14.767333	0.579333	-0.617753

	bedrooms_zed15	bathrooms_zed15	floors_zed15	waterfront_zed15	metascore_zed15	sqft_living_zed15	building_age_zed15	price_zed15
3	0.010000	0.006500	-0.005667	-0.000667	0.002000	-1.240000	0.050667	-0.046466
4	-0.002000	-0.003000	-0.006000	0.000000	-0.001333	-2.500000	-0.010000	0.006215

In [7]:

```
pd.plotting.scatter_matrix(correlated_df, figsize=(20, 20))
plt.show()
```

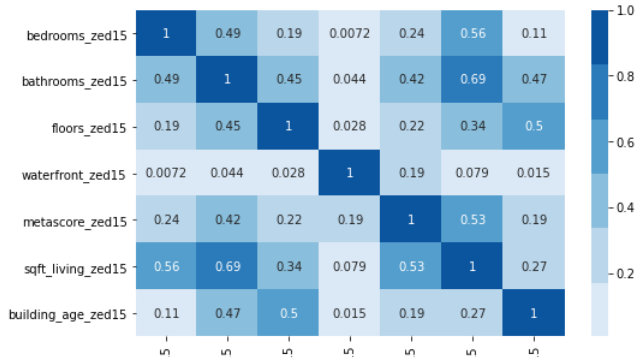

bedrooms_zed15
bathrooms_zed15
floors_zed15
waterfront_zed15
metascore_zed15
sqft_living_zed15
building_age_zed15
price_zed15

In [8]:

```
print(f"=================== df_features CORRELATION PLOT ======================")
plot_corr(df_features)
print()


for col_c in df_features.columns:
    print(f"\n============= vif for column {repr(col_c)} ==================")
    vif = calculate_vif(df=df_features, target_col=col_c, show_res=True)
    print(f"column {repr(col_c)} has vif of {vif}")
    print(f"============================================================\n")
```

```
=================== df_features CORRELATION PLOT ======================
```



In [9]:

```
# ====================================================
#       OLS Regression Model
#
# Michael Collins, Flatiron School
# 2020-10-30_0939_MDT
#
# ====================================================

ols = sf.check_model(
    df=df_clean,
    features_to_use=cols_feature,
    target_col=col_target,
    add_constant=False,
    show_summary=True,
    vif_threshold=3.0)
```

```
                                OLS Regression Results
==============================================================================================
Dep. Variable:            price_zed15   R-squared (uncentered):                   0.683
Model:                            OLS   Adj. R-squared (uncentered):              0.683
Method:                 Least Squares   F-statistic:                              6611.
Date:                Sat, 31 Oct 2020   Prob (F-statistic):                        0.00
Time:                        08:32:11   Log-Likelihood:                          6716.8
No. Observations:               21507   AIC:                                 -1.342e+04
Df Residuals:                   21500   BIC:                                 -1.336e+04
Df Model:                           7
Covariance Type:            nonrobust
============================================================================================
                           coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------------------
bedrooms_zed15        -1.1833      0.175     -6.765      0.000      -1.526      -0.840
bathrooms_zed15        2.2330      0.283      7.899      0.000       1.679       2.787
floors_zed15           0.3517      0.315      1.118      0.264      -0.265       0.968
waterfront_zed15      86.2473      1.724     50.027      0.000      82.868      89.626
metascore_zed15        6.3519      0.118     53.798      0.000       6.120       6.583
sqft_living_zed15      0.0255      0.000     95.633      0.000       0.025       0.026
building_age_zed15    -0.0241      0.007     -3.639      0.000      -0.037      -0.011
==============================================================================
Omnibus:                     3143.009   Durbin-Watson:                   2.012
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            11168.543
Skew:                           0.722   Prob(JB):                         0.00
Kurtosis:                       6.222   Cond. No.                     1.04e+04
==============================================================================

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 1.04e+04. This might indicate that there are
strong multicollinearity or other numerical problems.
Residuals failed test/tests
```

In [10]:

```
ols
```

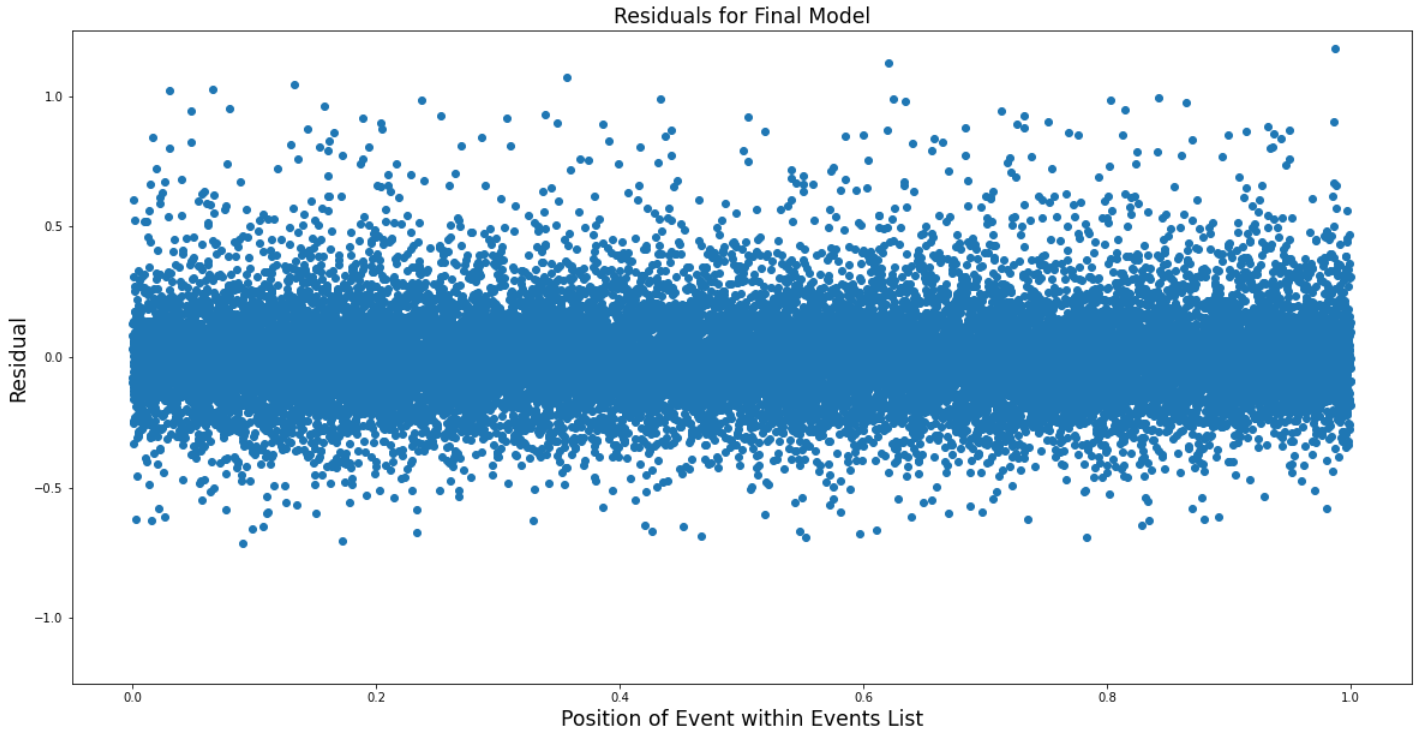
Out[10]:

```
<statsmodels.regression.linear_model.RegressionResultsWrapper at 0x16dfa063c50>
```

In [11]:

```
# plot residuals
ols_resid = ols.resid
x_axis = np.linspace(0, 1, len(ols_resid))
plt.figure(figsize=(20,10))
plt.scatter(x_axis, ols_resid)
y_min = -1.25
y_max = 1.25
plt.ylim(y_min, y_max)
plt.ylabel("Residual", fontsize='xx-large')
plt.xlabel("Position of Event within Events List", fontsize='xx-large')
plt.title("Residuals for Final Model", fontsize='xx-large')
plt.show()


print(f"len(ols.resid) = {len(ols.resid)}")
ols_eventIndex = df_clean[col_eventIndex]
ols_resid = ols.resid
ols_eventIndex_resid = list(zip(ols_eventIndex, ols_resid))
outlier_eventIndices = []
for eventIndex, resid in ols_eventIndex_resid:
    resid_min = -1
    resid_max = 1
    if not (resid_min <= resid <= resid_max):
        outlier_eventIndices.append(eventIndex)
print(f"====== outlier eventIndices =======")
print(f"outlier_eventIndices = {repr(outlier_eventIndices)}\n")
```

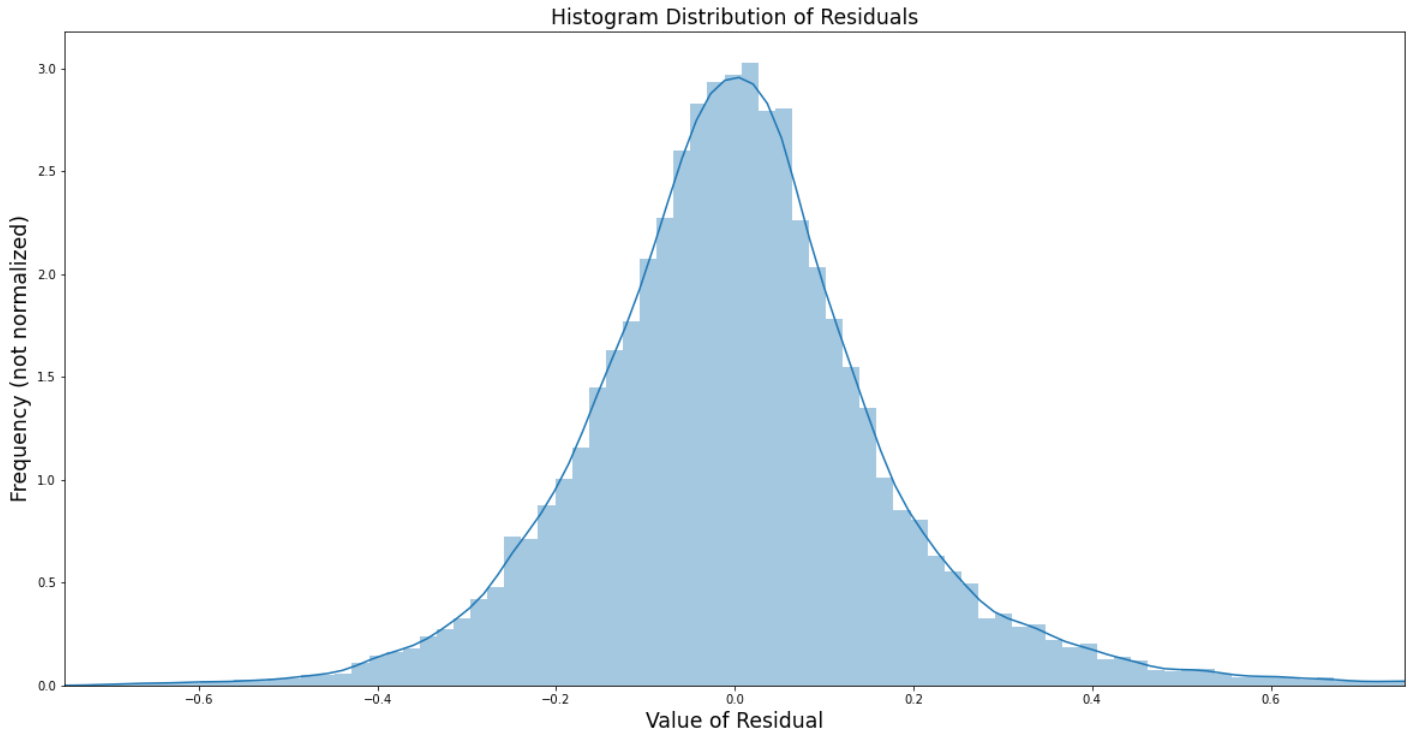


```
len(ols.resid) = 21507
====== outlier eventIndices =======
outlier_eventIndices = [656, 1418, 2862, 7693, 13398, 21328]
```

In [12]:

```
plt.figure(figsize=(20,10))
sns.distplot(ols.resid, bins=100)
x_min = np.min(ols.resid)
x_max = np.max(ols.resid)
x_min = -0.75
x_max = 0.75
plt.xlim(x_min, x_max)
plt.title("Histogram Distribution of Residuals", fontsize='xx-large')
plt.ylabel("Frequency (not normalized)", fontsize='xx-large')
plt.xlabel("Value of Residual", fontsize='xx-large')

plt.show()
```



In [13]:
```
# How can we test that our residuals are normal?
# H0: data is normal
# HA: data is not normal
scs.shapiro(ols.resid)

# p = 0.87 -> fail to reject the null, therefore residuals are normally distributed
```

Out[13]:
```
ShapiroResult(statistic=0.9581159353256226, pvalue=0.0)
```

In [14]:
```
df_map = df.loc[df[col_eventValid] == True]
display(df_map)
```

	eventIndex	eventValid	id	date	price	bedrooms	bathrooms	sqft_living	sqft_lot	floors	...	building_age_phi15	interior_age_mean15	interior_age_median15	interior_age_diff15	interior_age_
0	0	1	7129300520	2014-10-13	221900.0	3	1.00	1180	5650	1.0	...	-5.0	81.066667	80.0	-16.066667	
1	1	1	6414100192	2014-12-09	538000.0	3	2.25	2570	7242	2.0	...	0.0	63.133333	69.0	-34.133333	
2	2	1	5631500400	2015-02-25	180000.0	2	1.00	770	10000	1.0	...	5.0	29.066667	25.0	57.933333	
3	3	1	2487200875	2014-12-09	604000.0	4	3.00	1960	5000	1.0	...	-5.0	49.933333	65.0	5.066667	
4	4	1	1954400510	2015-02-18	510000.0	3	2.00	1680	8080	1.0	...	0.0	34.000000	33.0	-1.000000	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
21592	21592	1	263000018	2014-05-21	360000.0	3	2.50	1530	1131	3.0	...	-5.0	34.733333	21.0	-23.733333	
21593	21593	1	6600060120	2015-02-23	400000.0	4	2.50	2310	5813	2.0	...	-5.0	35.800000	26.0	-29.800000	
21594	21594	1	1523300141	2014-06-23	402101.0	2	0.75	1020	1350	2.0	...	-5.0	46.133333	17.0	-35.133333	
21595	21595	1	291310100	2015-01-16	400000.0	3	2.50	1600	2388	2.0	...	5.0	15.533333	15.0	0.466667	
21596	21596	1	1523300157	2014-10-15	325000.0	2	0.75	1020	1076	2.0	...	-5.0	46.133333	17.0	-34.133333	

21507 rows × 163 columns

In [15]:

```
print(f"col_lat = {repr(col_lat)}")
print(f"col_long = {repr(col_long)}")
print()


col_price_mean = f"price_mean{ext_K}"
col_log10_price_mean = f"log10_price_mean{ext_K}"
map_price_mean = df_map[col_price_mean]
map_log10_price_mean = [np.log10(pm) for pm in map_price_mean]
df_map[col_log10_price_mean] = map_log10_price_mean
df_map['resid'] = ols.resid
df_map['resid_qcut'] = pd.qcut(df_map['resid'], 10, labels=False)
display(df_map)
```

```
col_lat = 'lat'
col_long = 'long'
```

	eventIndex	eventValid	id	date	price	bedrooms	bathrooms	sqft_living	sqft_lot	floors	...	interior_age_diff15	interior_age_delta15	interior_age_sigma15	interior_age_MAD15	interior_age_z
0	0	1	7129300520	2014-10-13	221900.0	3	1.00	1180	5650	1.0	...	-16.066667	-15.0	27.805195	22.0	-
1	1	1	6414100192	2014-12-09	538000.0	3	2.25	2570	7242	2.0	...	-34.133333	-40.0	15.244088	2.0	-
2	2	1	5631500400	2015-02-25	180000.0	2	1.00	770	10000	1.0	...	57.933333	62.0	14.073458	8.0	
3	3	1	2487200875	2014-12-09	604000.0	4	3.00	1960	5000	1.0	...	5.066667	-10.0	33.235456	30.0	
4	4	1	1954400510	2015-02-18	510000.0	3	2.00	1680	8080	1.0	...	-1.000000	0.0	3.425395	1.0	-
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
21592	21592	1	263000018	2014-05-21	360000.0	3	2.50	1530	1131	3.0	...	-23.733333	-10.0	31.890368	9.0	-
21593	21593	1	6600060120	2015-02-23	400000.0	4	2.50	2310	5813	2.0	...	-29.800000	-20.0	25.771302	20.0	-
21594	21594	1	1523300141	2014-06-23	402101.0	2	0.75	1020	1350	2.0	...	-35.133333	-6.0	46.173393	9.0	-
21595	21595	1	291310100	2015-01-16	400000.0	3	2.50	1600	2388	2.0	...	0.466667	1.0	1.087300	0.0	
21596	21596	1	1523300157	2014-10-15	325000.0	2	0.75	1020	1076	2.0	...	-34.133333	-5.0	46.173393	9.0	-

21507 rows × 166 columns

In [16]:

```
# ========================================================
#   Make a pretty map of selected data from the data frame.
# ========================================================

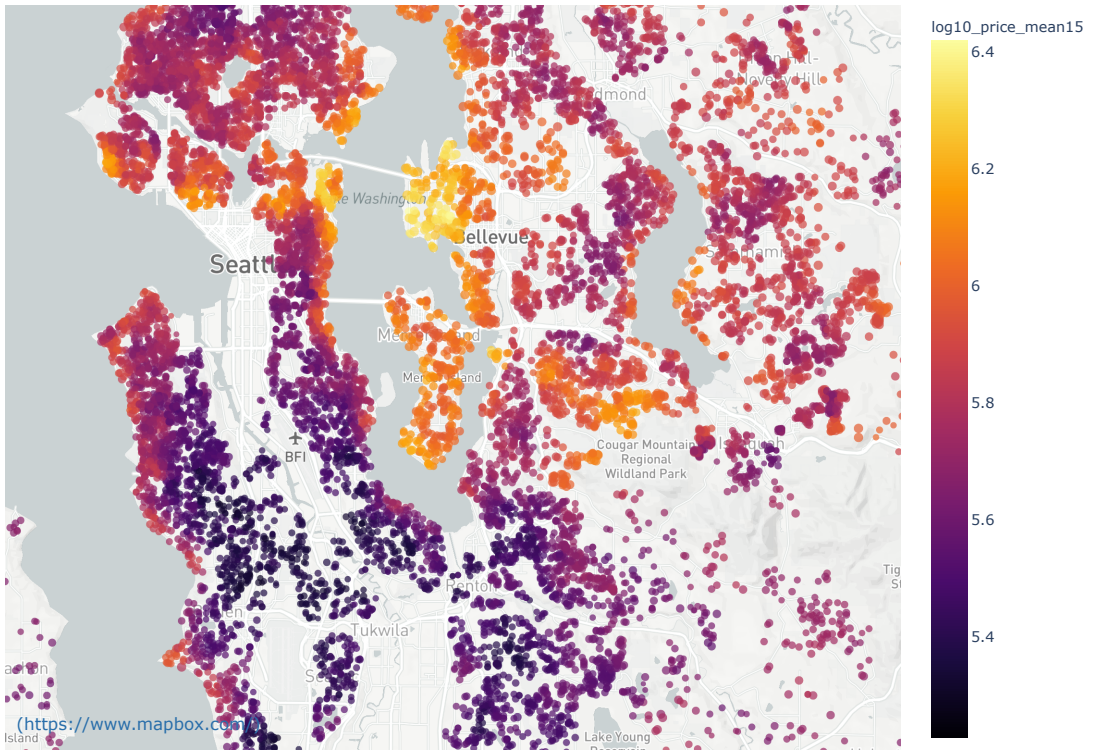
mapbox_access_token = open(r"c:\.mapbox\access_token").read()

px.set_mapbox_access_token(mapbox_access_token)

fig = px.scatter_mapbox(df_map,
                        lat=col_lat,
                        lon=col_long,
                        color=col_log10_price_mean,
                        size=col_grade,
                        color_continuous_scale="Inferno",
                        size_max=6,
                        zoom=10, title=f"log10(Mean Price of {ext_K} nearest Neighbors)")
fig.update_layout(autosize=False,
                  width=1000,
                  height=800)

fig.show()
```

log10(Mean Price of 15 nearest Neighbors)



In [17]:

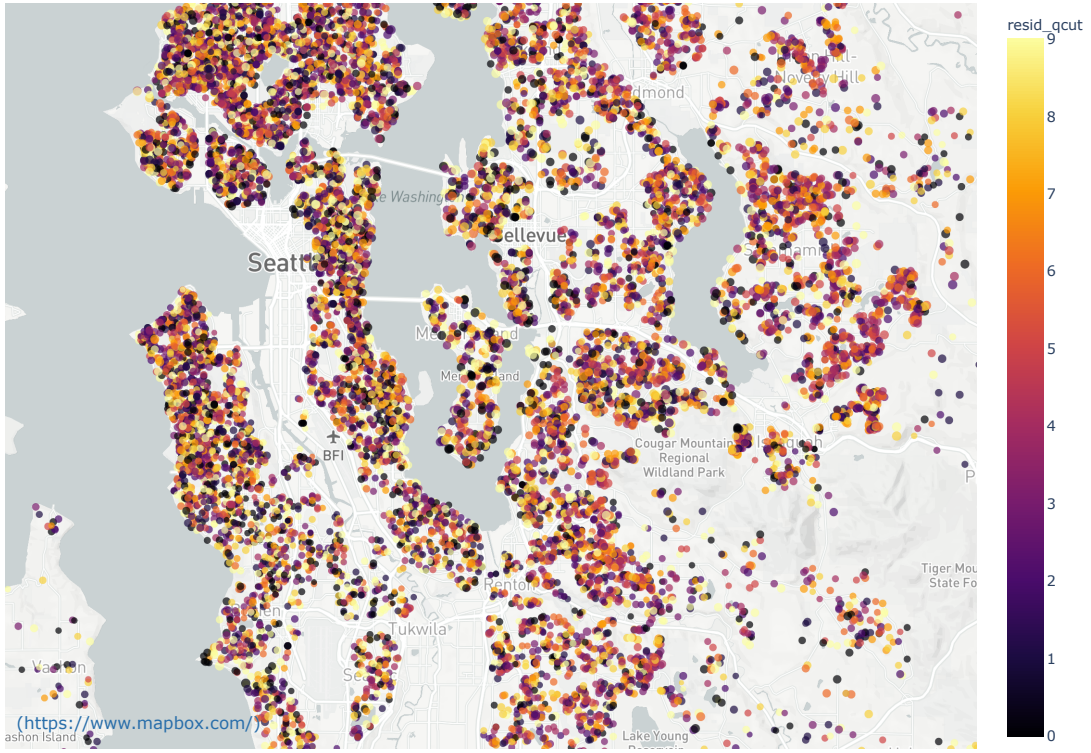
```
# ============================================================
#   Make a pretty map of selected data from the data frame.
# ============================================================

mapbox_access_token = open(r"c:\.mapbox\access_token").read()

px.set_mapbox_access_token(mapbox_access_token)

fig = px.scatter_mapbox(df_map,
                        lat=col_lat,
                        lon=col_long,
                        color='resid_qcut',
                        size=col_grade,
                        color_continuous_scale="Inferno",
                        size_max=6,
                        zoom=10, title="residual deciles by location")
fig.update_layout(autosize=False,
                  width=1000,
                  height=800)
fig.show()
```

residual deciles by location



In [18]:

```
1 print(df_raw.columns)
```

```
Index(['id', 'date', 'price', 'bedrooms', 'bathrooms', 'sqft_living',
       'sqft_lot', 'floors', 'waterfront', 'view', 'condition', 'grade',
       'sqft_above', 'sqft_basement', 'yr_built', 'yr_renovated', 'zipcode',
       'lat', 'long', 'sqft_living15', 'sqft_lot15', 'KNN', 'building_age',
       'interior_age', 'log10_price'],
      dtype='object')
```

In [19]:

```
# ================================================
#    Take a detailed look at the raw values
#    in columns whose values may be categorical
#
#    Michael Collins, Flatiron School
#    2020-10-30_0455_MDT
# ================================================

cols_examine = list(df_raw.columns)
cols_summarized = []
quanta_all = []
for col_c in cols_examine:
    items_c = sorted(list(dict(df_raw[col_c].value_counts()).items()))
    num_c = len(items_c)
    if num_c < 50:
        cols_summarized.append(col_c)
        print(f"==== {repr(col_c)} =====")
        quanta_c = [repr(k) for k, v in items_c]
        quanta_all.append(f"quanta_{col_c} = {quanta_c}")
        for k, v in items_c:
            s_k = str(k) + " " * (8-len(str(k)))
            print(s_k, v)
        print()

print(f"==== COLUMNS_SUMMARIZED =====")
print(f"cols_summarized = {repr(cols_summarized)}\n")

print(f"==== QUANTA_SUMMARIZED =====")
print(f"quanta_summarized =")
for s in quanta_all:
    print(s)
print()


```

```
==== 'bedrooms' =====
1        196
2        2760
3        9824
4        6882
5        1601
6        272
7        38
8        13
9        6
10       3
11       1
33       1

==== 'bathrooms' =====
0.5      4
0.75     71
1.0      3851
1.25     9
1.5      1445
1.75     3048
2.0      1930
2.25     2047
2.5      5377
2.75     1185
3.0      753
3.25     589
3.5      731
3.75     155
4.0      136
4.25     79
4.5      100
4.75     23
5.0      21
5.25     13
```

```
5.5      10
5.75     4
6.0      6
6.25     2
6.5      2
6.75     2
7.5      1
7.75     1
8.0      2

==== 'floors' =====
1.0      10673
1.5      1910
2.0      8235
2.5      161
3.0      611
3.5      7

==== 'waterfront' =====
0        21451
1        146

==== 'view' =====
0        19485
1        330
2        957
3        508
4        317

==== 'condition' =====
1        29
2        170
3        14020
4        5677
5        1701

==== 'grade' =====
3        1
4        27
5        242
6        2038
7        8974
8        6065
9        2615
10       1134
11       399
12       89
13       13

==== COLUMNS_SUMMARIZED =====
cols_summarized = ['bedrooms', 'bathrooms', 'floors', 'waterfront', 'view', 'condition', 'grade']

==== QUANTA_SUMMARIZED =====
quanta_summarized =
quanta_bedrooms = ['1', '2', '3', '4', '5', '6', '7', '8', '9', '10', '11', '33']
quanta_bathrooms = ['0.5', '0.75', '1.0', '1.25', '1.5', '1.75', '2.0', '2.25', '2.5', '2.75', '3.0', '3.25', '3.5', '3.75', '4.0', '4.25', '4.5', '4.75', '5.0', '5.25', '5
25', '6.5', '6.75', '7.5', '7.75', '8.0']
quanta_floors = ['1.0', '1.5', '2.0', '2.5', '3.0', '3.5']
quanta_waterfront = ['0', '1']
quanta_view = ['0', '1', '2', '3', '4']
quanta_condition = ['1', '2', '3', '4', '5']
quanta_grade = ['3', '4', '5', '6', '7', '8', '9', '10', '11', '12', '13']
```

In [ ]:

```
1
```