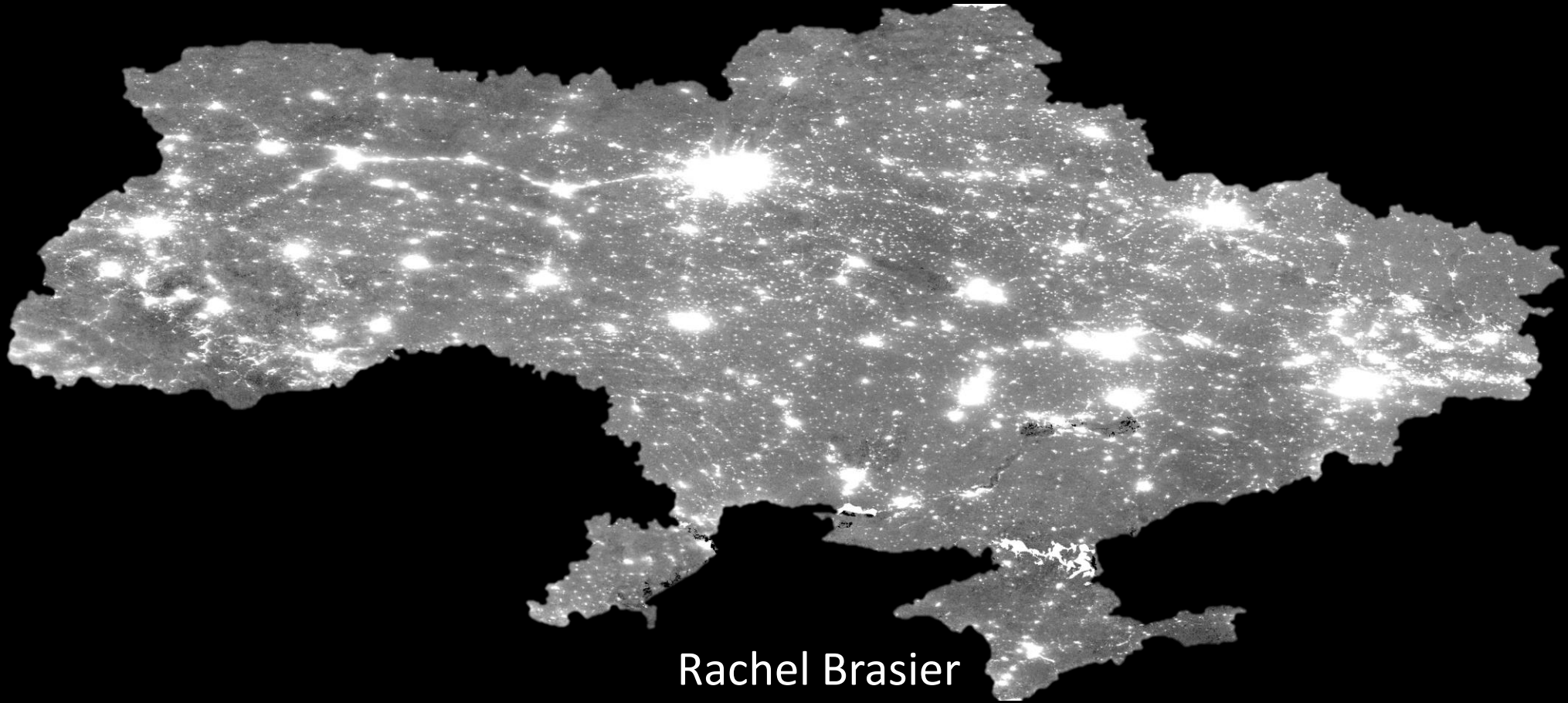


# Nighttime Lights in the Donbas:

## Modeling Conflict Migration Patterns in Ukraine Using Satellite Imagery



Rachel Brasier  
5 August 2021

# Presentation Outline

- Goal: share information about data and mapping resources that may be useful to Ukraine researchers
- Review of literature
- Data sources and methods
- Monthly radiance time series for selected cities
  - Note: radiance is measure of nighttime lights
- Population change vs. radiance change maps
- Linear models (basic, preliminary)
- Conclusion

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- Conclusion
- *Does this data fit with the narrative?*

# Project Purpose

- This project explores the movements of internally displaced persons (IDP's) in Ukraine as a consequence of the conflict in the Donbas.
- The United Nations Refugee Agency ([UNHCR](#)): 1.5 million IDP's were primarily relocated to cities in central and Eastern Ukraine.
- Proper measurement of this population shift is essential for understanding the dynamics and effects of the conflict.
- Official Ukrainian regional population statistics could be misleading; the last Ukrainian census was in 2001.
- Can we track population shifts using nighttime lights data?

# Ukrainian Regions and Major Cities



0 50 100 200 Kilometers



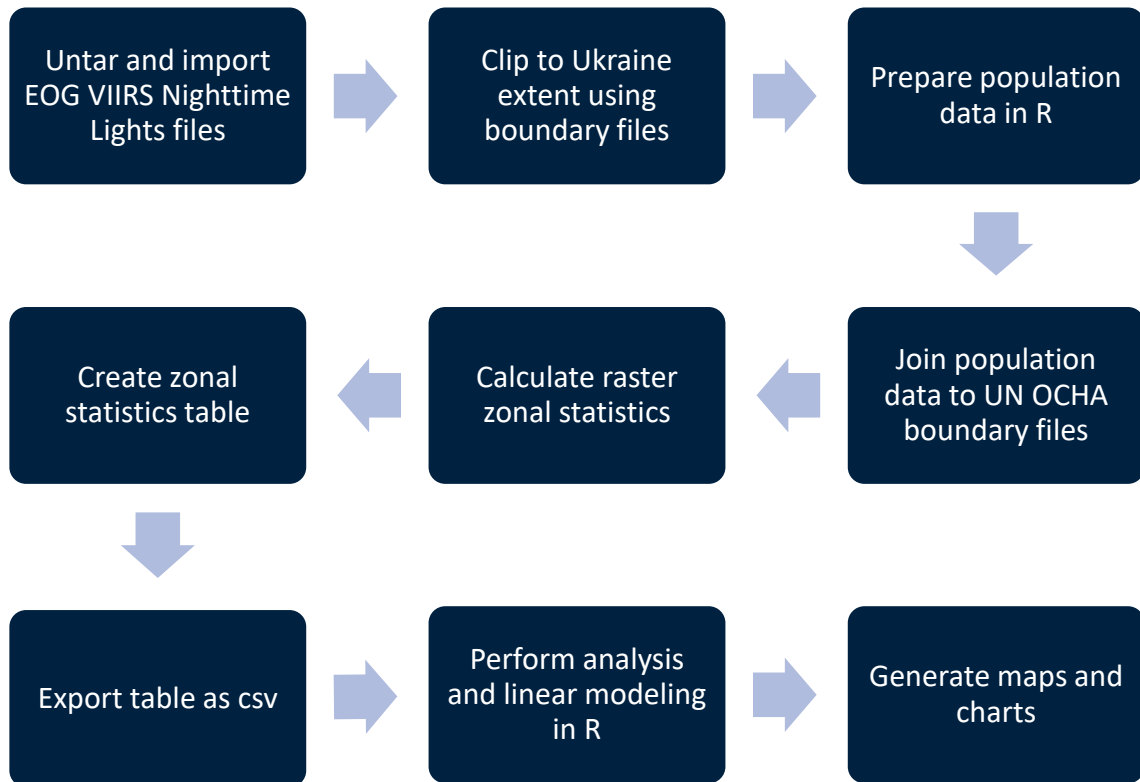
# Review of Literature

- Nighttime lights in conflict zones
  1. Witmer & O'Loughlin, "Detecting the Effects of Wars in the Caucasus Regions of Russia and Georgia Using Radiometrically Normalized DMSP-OLS Nighttime Lights Imagery" (2011)
  2. Jiang et al., "Ongoing Conflict Makes Yemen Dark: From the Perspective of Nighttime Light" (2017)
- Nighttime lights for population estimation
  1. Mellander et al., "Night-Time Light Data: A Good Proxy Measure for Economic Activity?" (2015)
  2. Bharti et al., "Remotely Measuring Populations During a Crisis by Overlaying Two Data Sources" (2015)

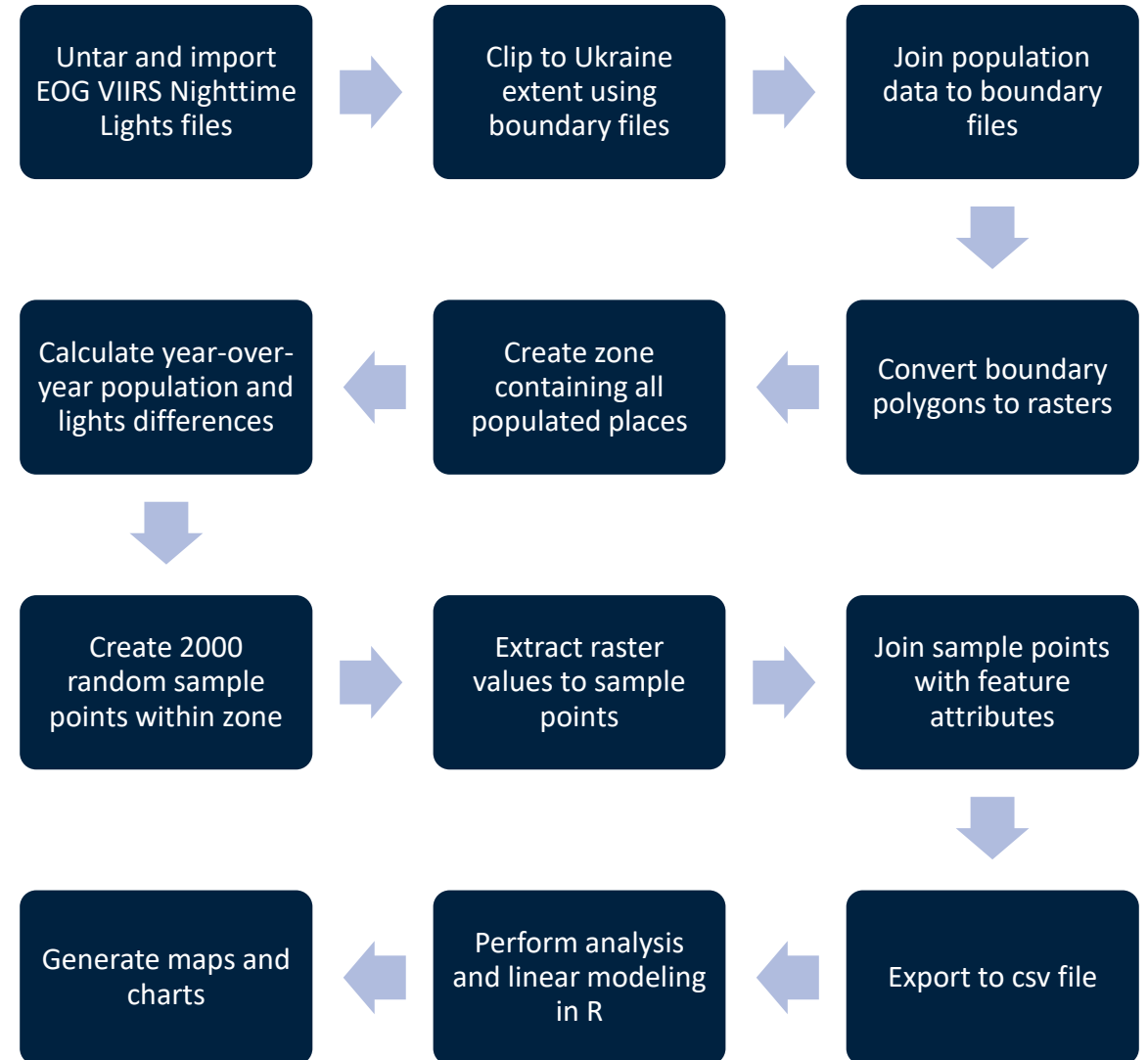
# Data Sources and Processes

- State Statistics Service of Ukraine (Ukrstat)
  - Annual population estimates, “carried out on the basis of available administrative data on state registration of births and deaths and change of residence registration”
- UN OCHA Ukraine
  - Spatial polygons of sub-national geographies
- Earth Observation Group, Payne Institute for Public Policy
  - VIIRS satellite day-night band (DNB)
    - Visible Infrared Imaging Radiometer Suite
    - Wavelengths 0.5 to 0.9  $\mu\text{m}$  (visible, near-IR)
    - Measurement unit:  $\text{nW}/\text{cm}^2/\text{sr}$
    - Image CRS and resolution: EPSG 4326, 15 arc-seconds (300-500m)
    - Monthly calibrated average radiance GeoTIFF images produced by EOG

# Method 1: City-Level Analysis



# Method 2: Cell-by-Cell Analysis





# Population Data Process

## 5. Чисельність наявного населення в розрізі регіонів районів, міст, селищ міського типу (за оцінкою)

	(на 1 січня; осіб)		
	2014	2015	2016
<b>УКРАЇНА</b> <i>Ukraine</i>	<b>45 426 249</b>	<b>42 929 298</b>	<b>42 760 516</b>
Міське населення	31 339 017	29 675 358	29 584 952
Сільське населення	14 087 232	13 253 940	13 175 564
<b>Автономна Республіка Крим</b>	1 967 259	...	...
<b>Донецька область</b> <i>Donetsk Oblast</i>	4 343 882	4 297 250	4 265 145
Міське населення	3 940 126	3 897 868	3 870 115
Сільське населення	403 756	399 382	395 030
<b>Донецьк (міськрада)</b> <i>Donetsk Metro</i>	965 828	952 139	944 915
Міське населення	964 262	950 579	943 355
м. Донецьк	949 825	936 257	929 063
м. Моспине	10 745	10 635	10 605
смт Горбачево-Михайлівка	919	917	917
смт Ларине	2 773	2 770	2 770
Сільське населення	1 566	1 560	1 560
м. Авдіївка	35 090	34 728	34 238
<b>Артемівськ (міськрада)</b>	103 493	103 027	102 116
Міське населення	103 493	103 027	102 116
м. Бахмут (колишнє м. Артемівськ) <sup>1</sup>	77 474	77 177	76 599
м. Соледар <i>Bakhmut City (formerly Artemivsk City)</i>	11 560	11 486	11 353
м. Часів Яр	13 817	13 721	13 522
смт Красна Гора	642	643	642

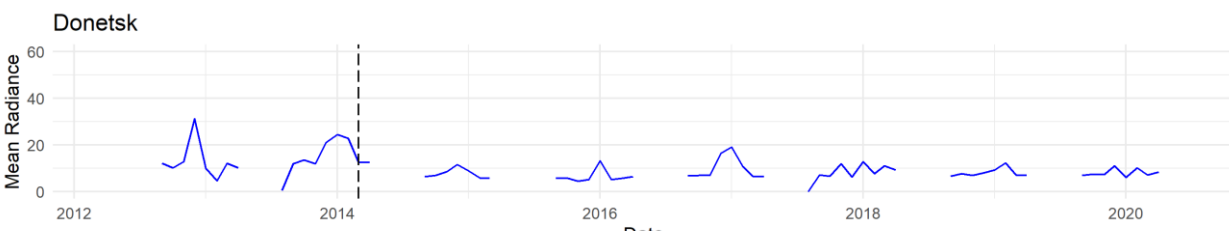
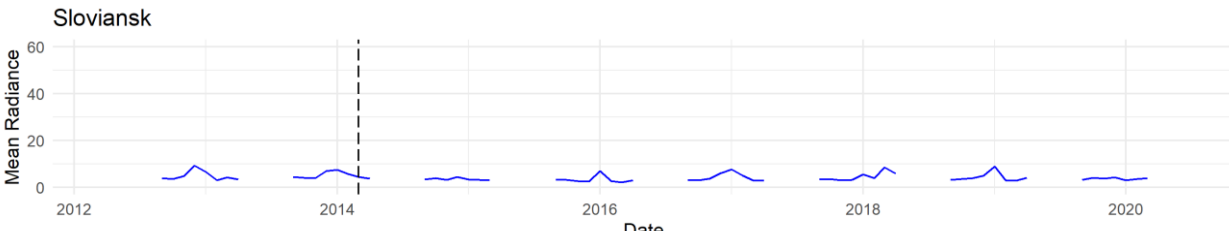
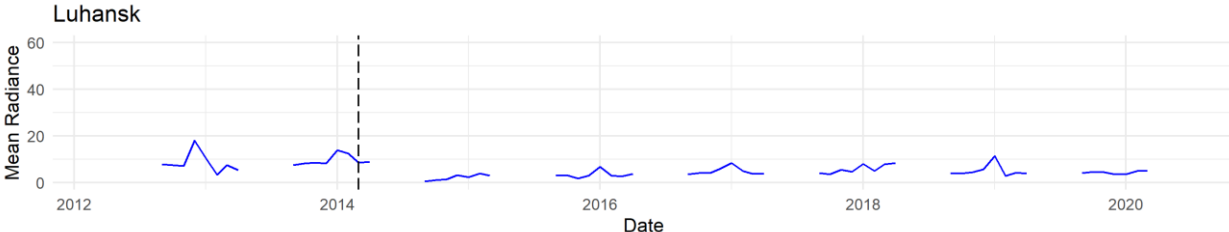
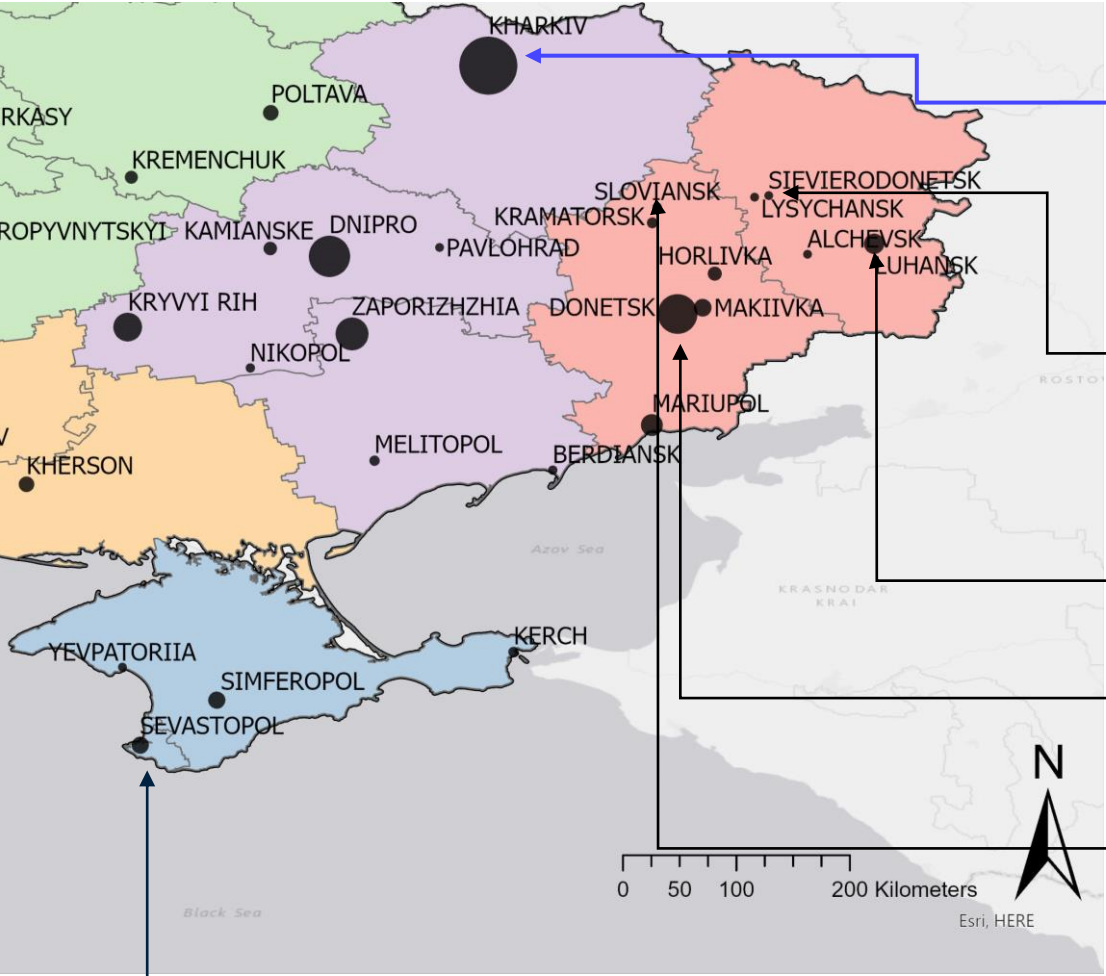
- Table from Ukrstat is nested using spaces
- Programmatically un-nest data using string functions ([see R script](#))
- Merge annual data tables using long-form names (Ukrainian Cyrillic)
  - Also match by former name, if applicable
- Merge with UN OCHA Ukraine administrative districts table

id15	id16	y2014
Донецька область м. Донецьк	Донецька область м. Донецьк	949825
Донецька область м. Моспине	Донецька область м. Моспине	10745
Донецька область смт Горбачево-Михайлівка	Донецька область смт Горбачево-Михайлівка	919
Донецька область смт Ларине	Донецька область смт Ларине	2773
Донецька область м. Авдіївка	Донецька область м. Авдіївка	35090
Донецька область м. Артемівськ	Донецька область м. Бахмут	77474
<i>Donetsk Oblast, Artemivsk City</i>	<i>Donetsk Oblast, Bakhmut City</i>	
Донецька область м. Соледар	Донецька область м. Соледар	11560
Донецька область м. Часів Яр	Донецька область м. Часів Яр	13817
Донецька область смт Красна Гора	Донецька область смт Красна Гора	642

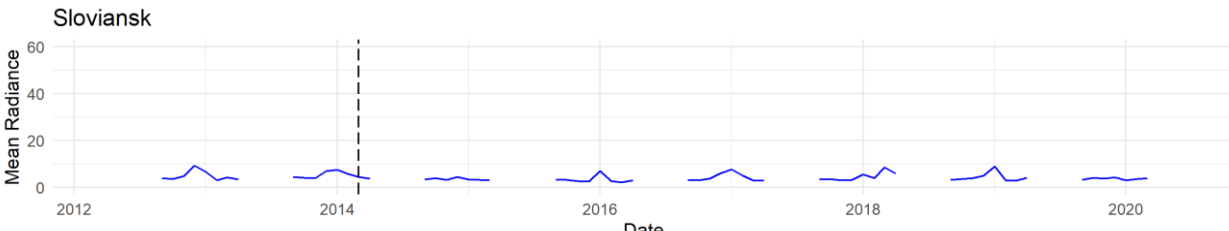
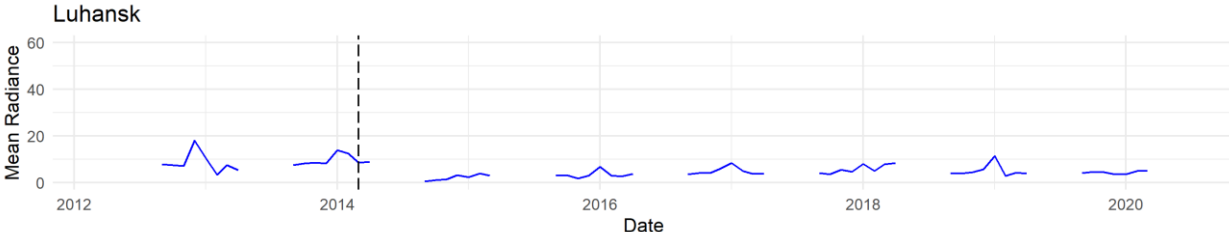
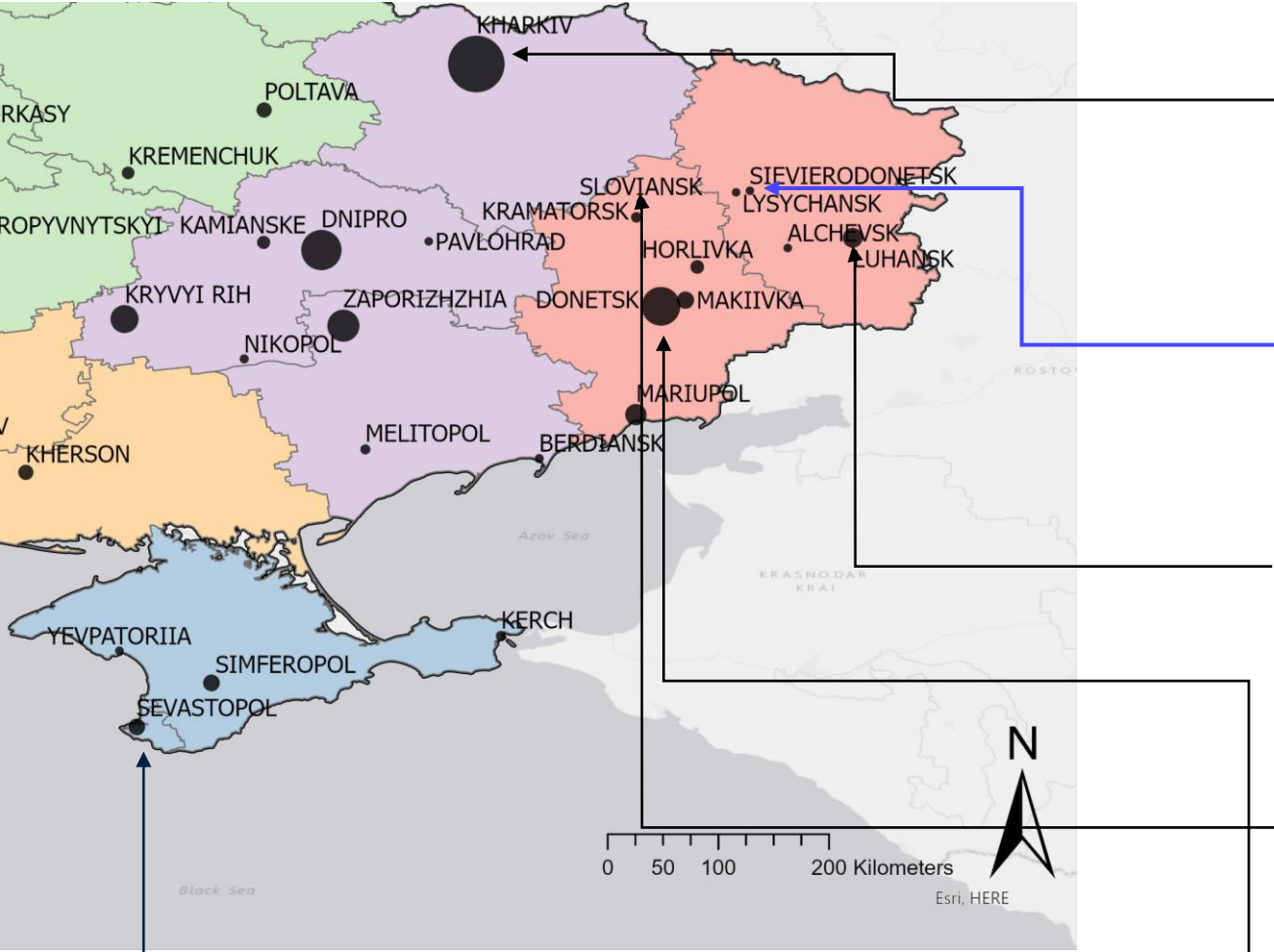


<sup>1</sup> Відповідно до Постанови Верховної Ради України від 4 лютого 2016 року № 984-VIII

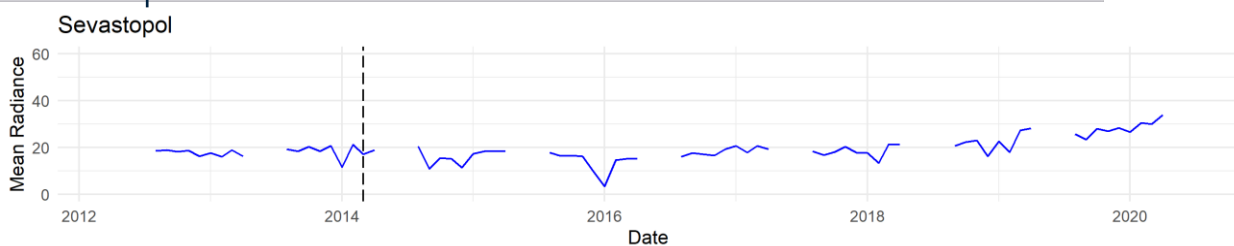
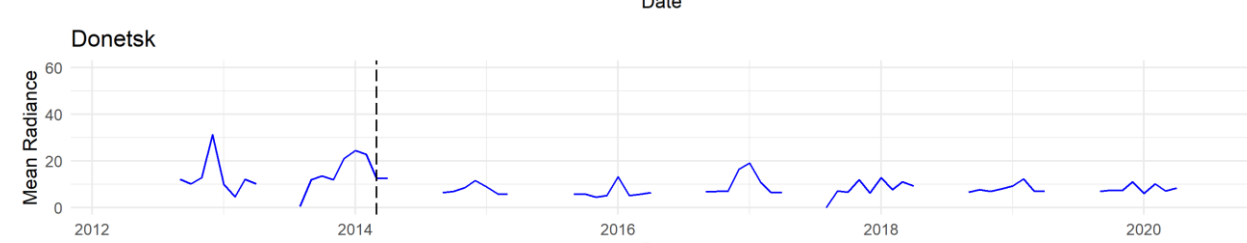
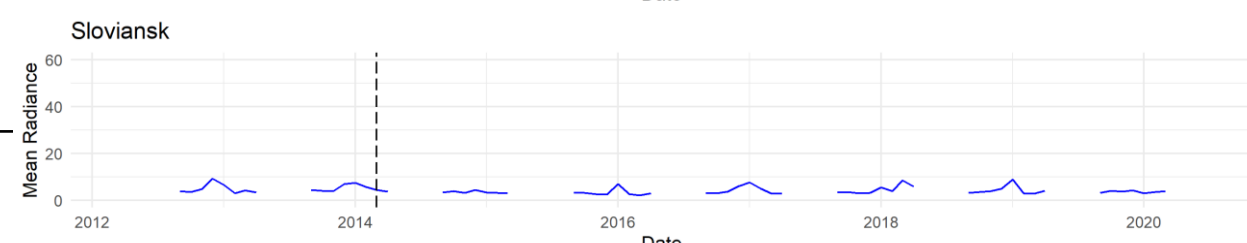
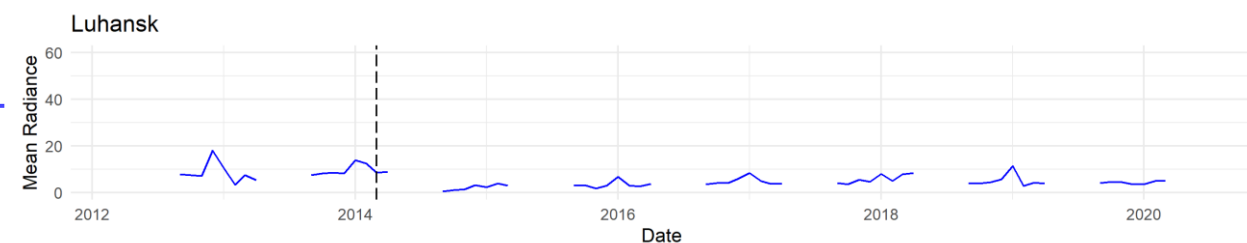
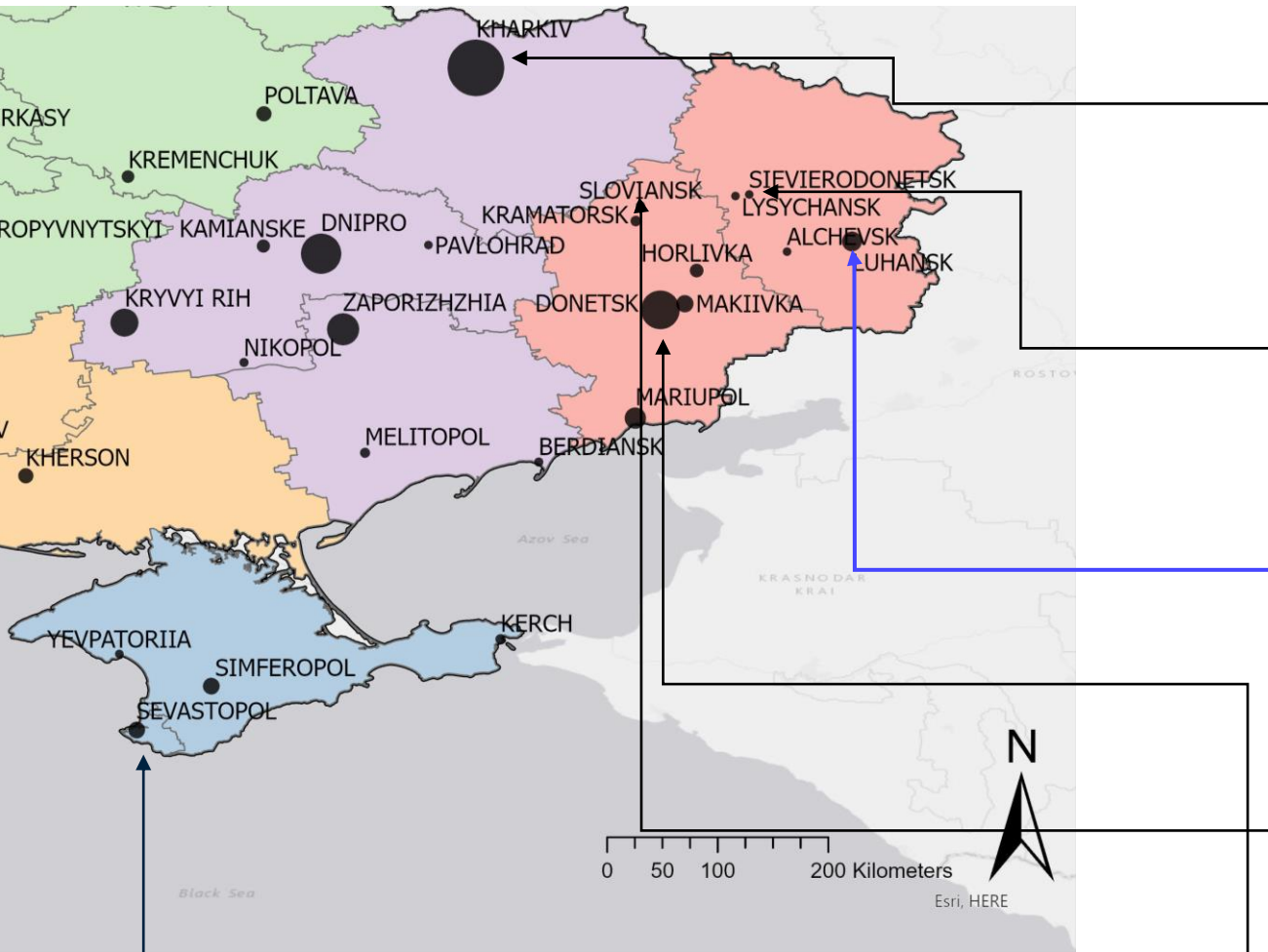
# Monthly Radiance Time Series



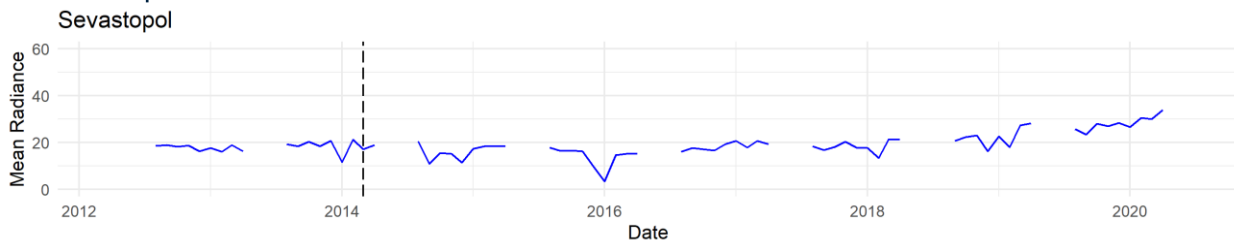
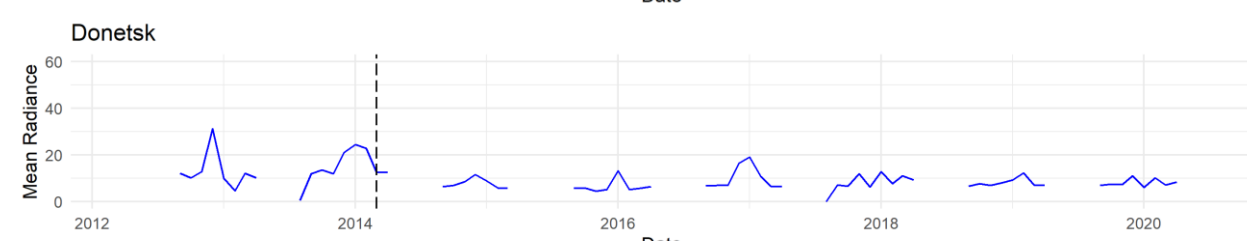
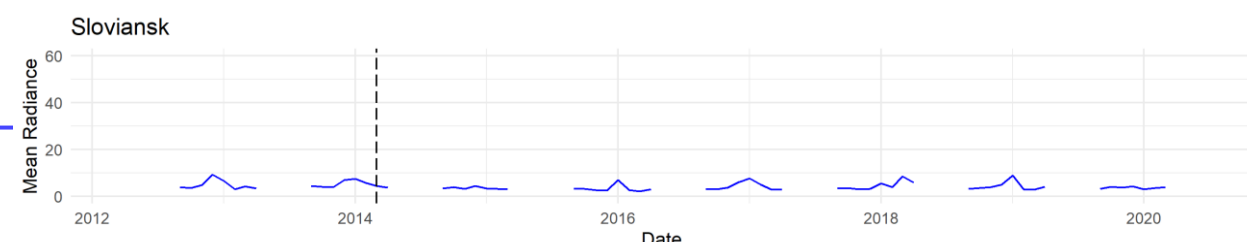
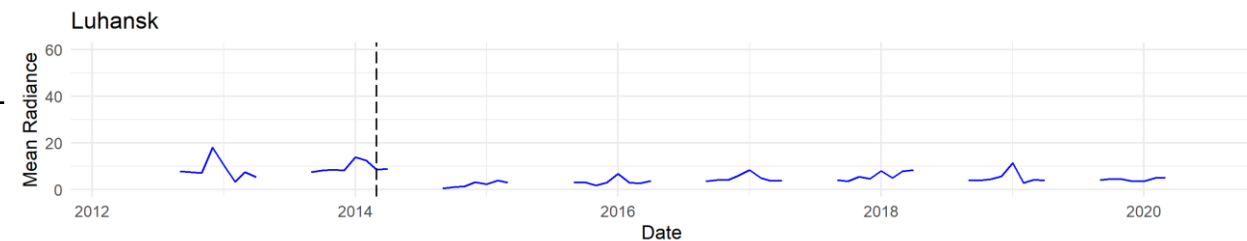
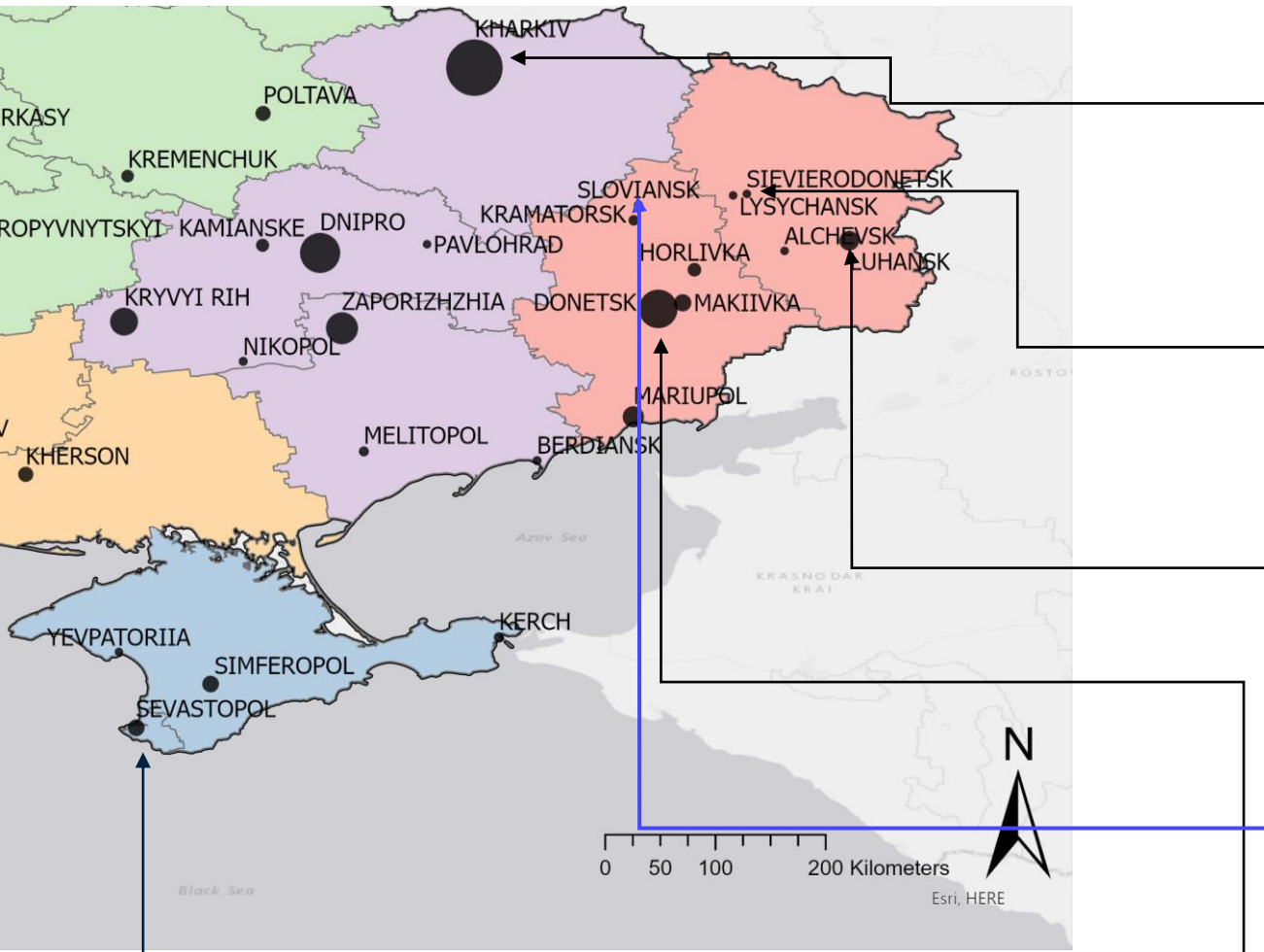
# Monthly Radiance Time Series



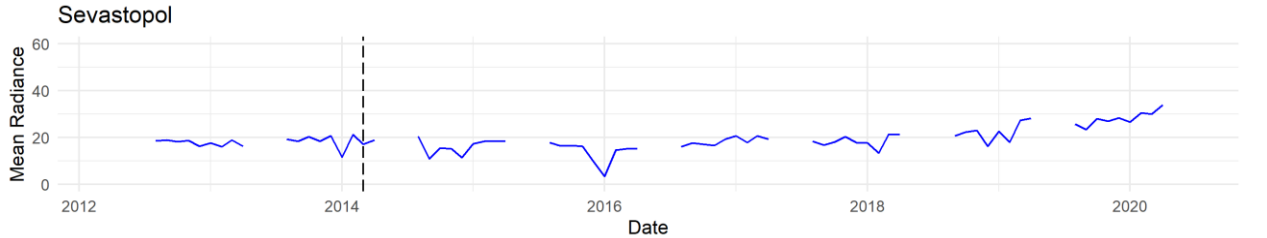
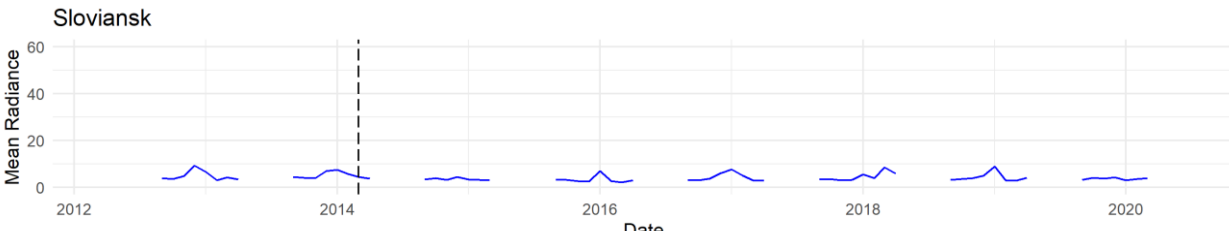
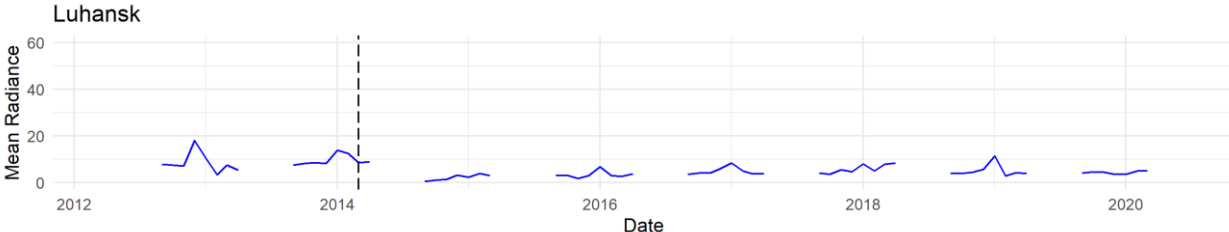
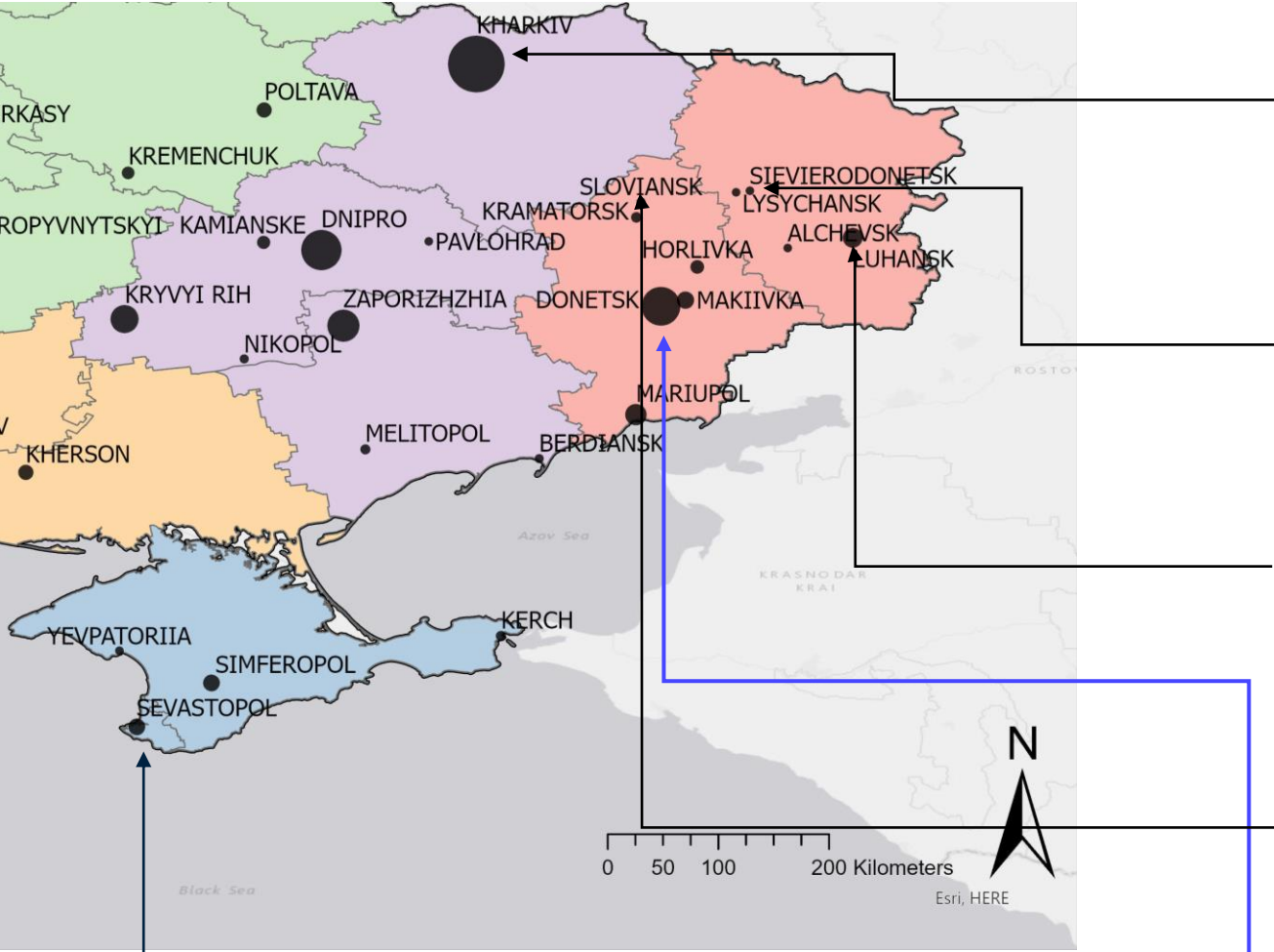
# Monthly Radiance Time Series



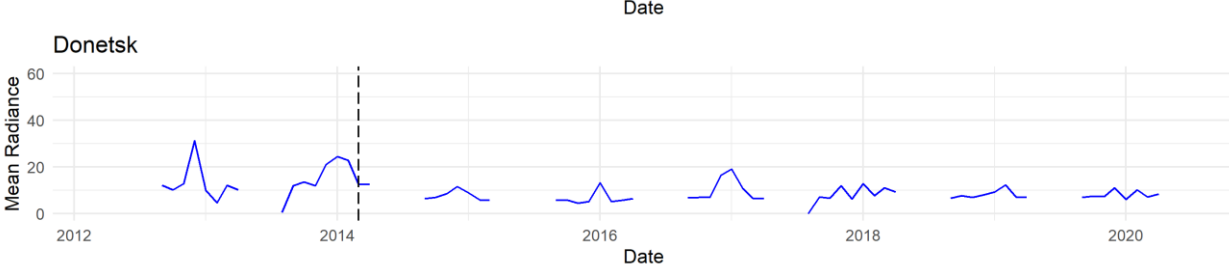
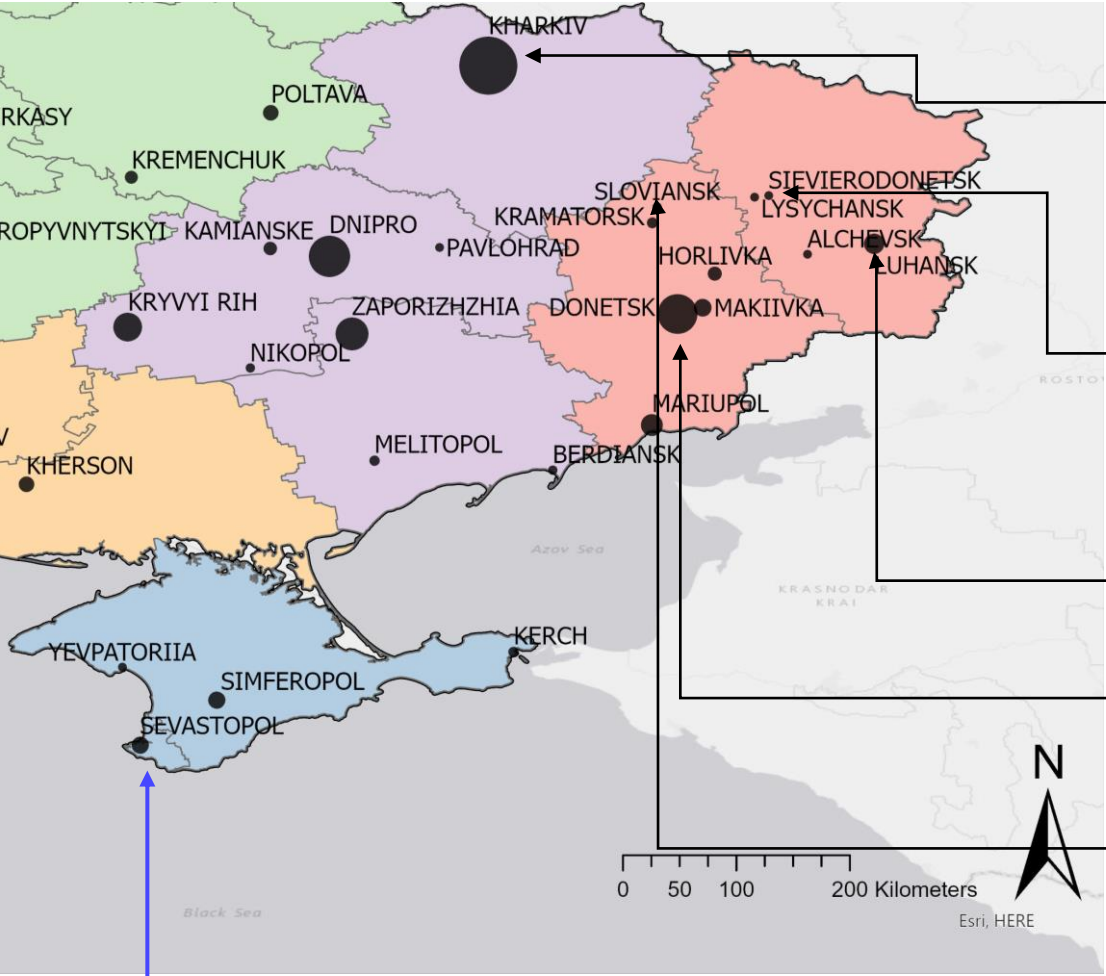
# Monthly Radiance Time Series



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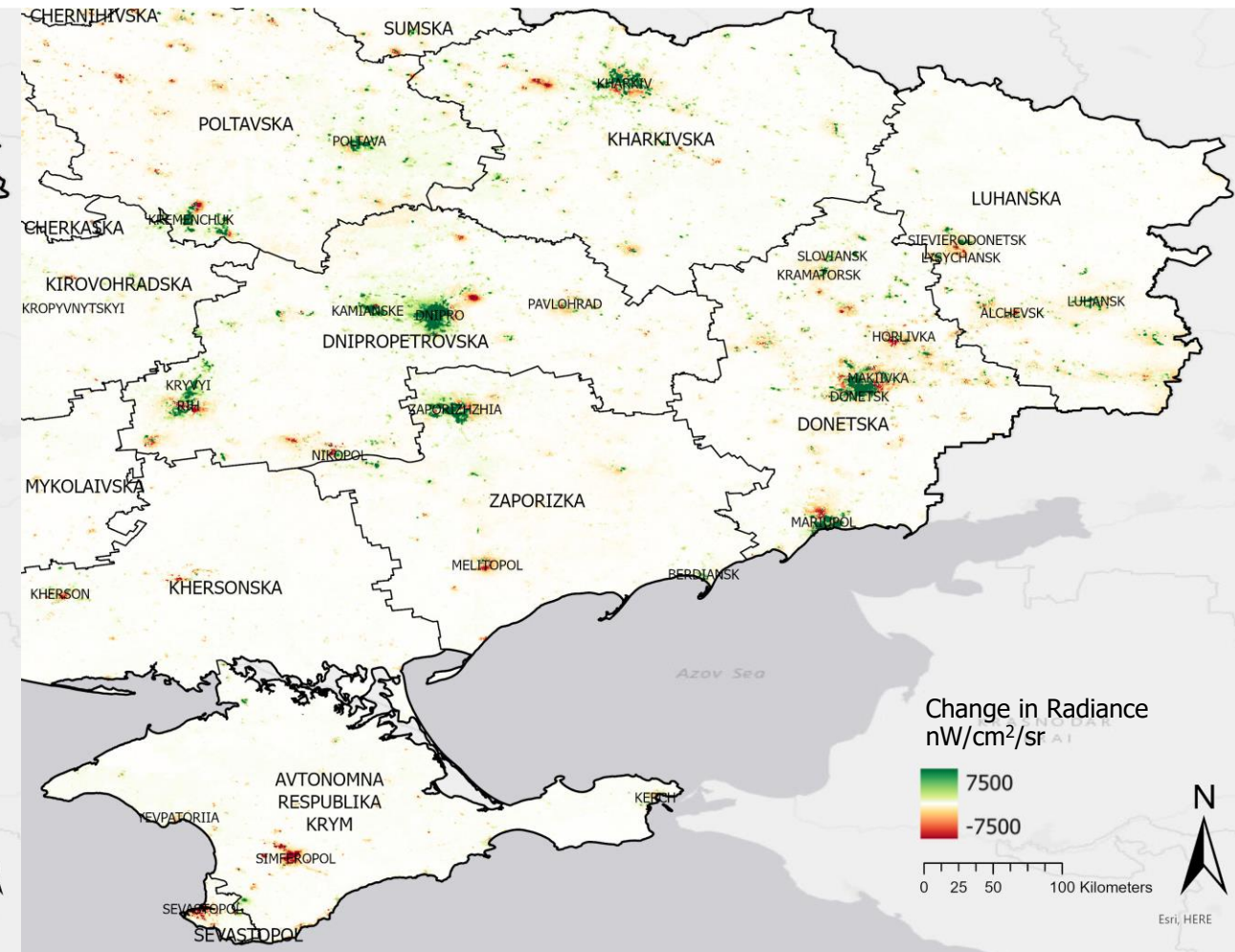
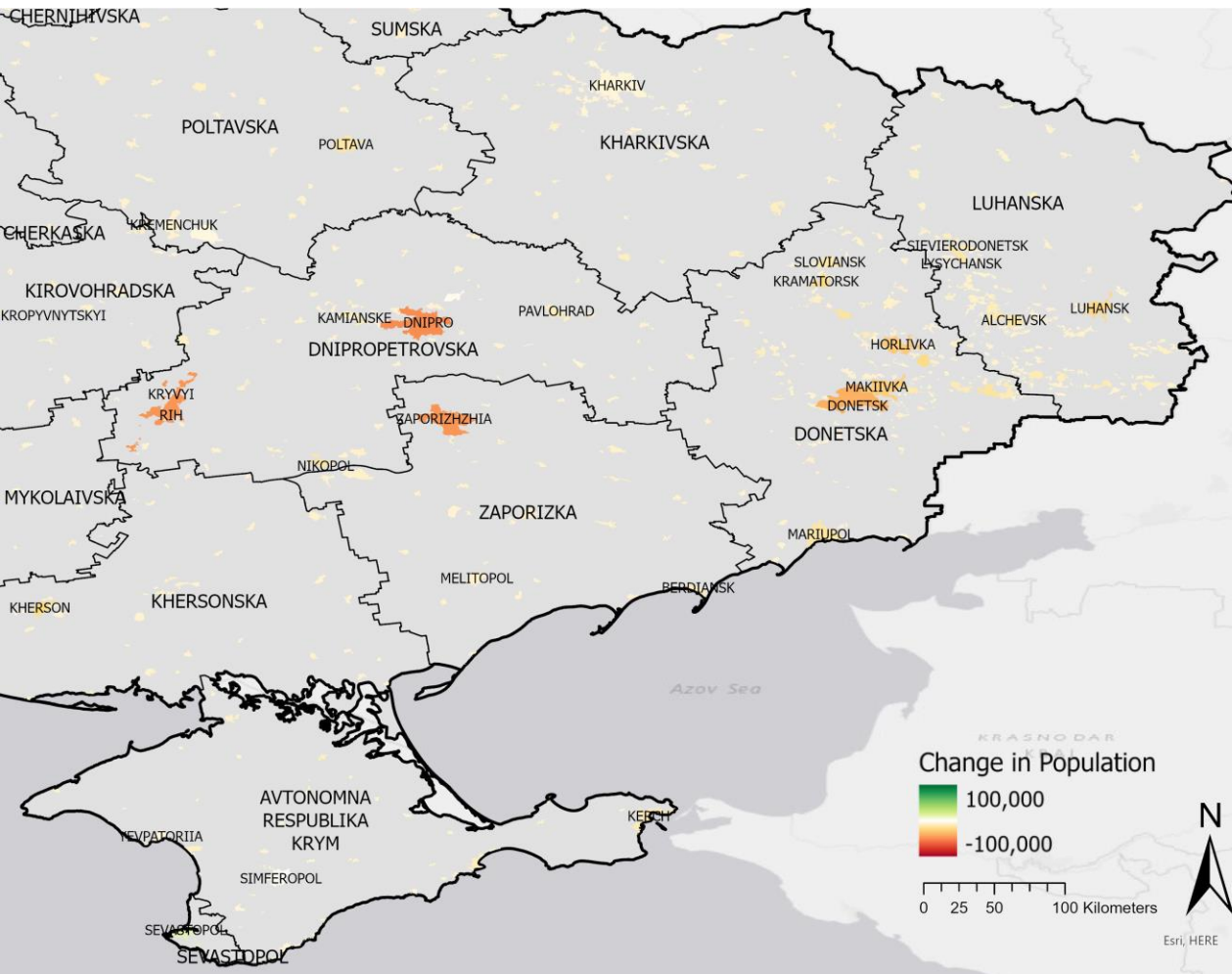


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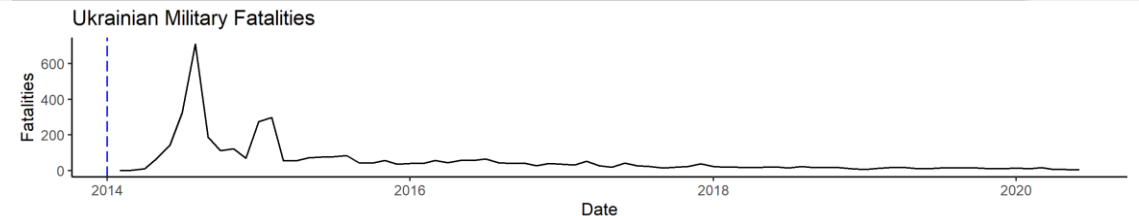


# Population Change

# Radiance Change



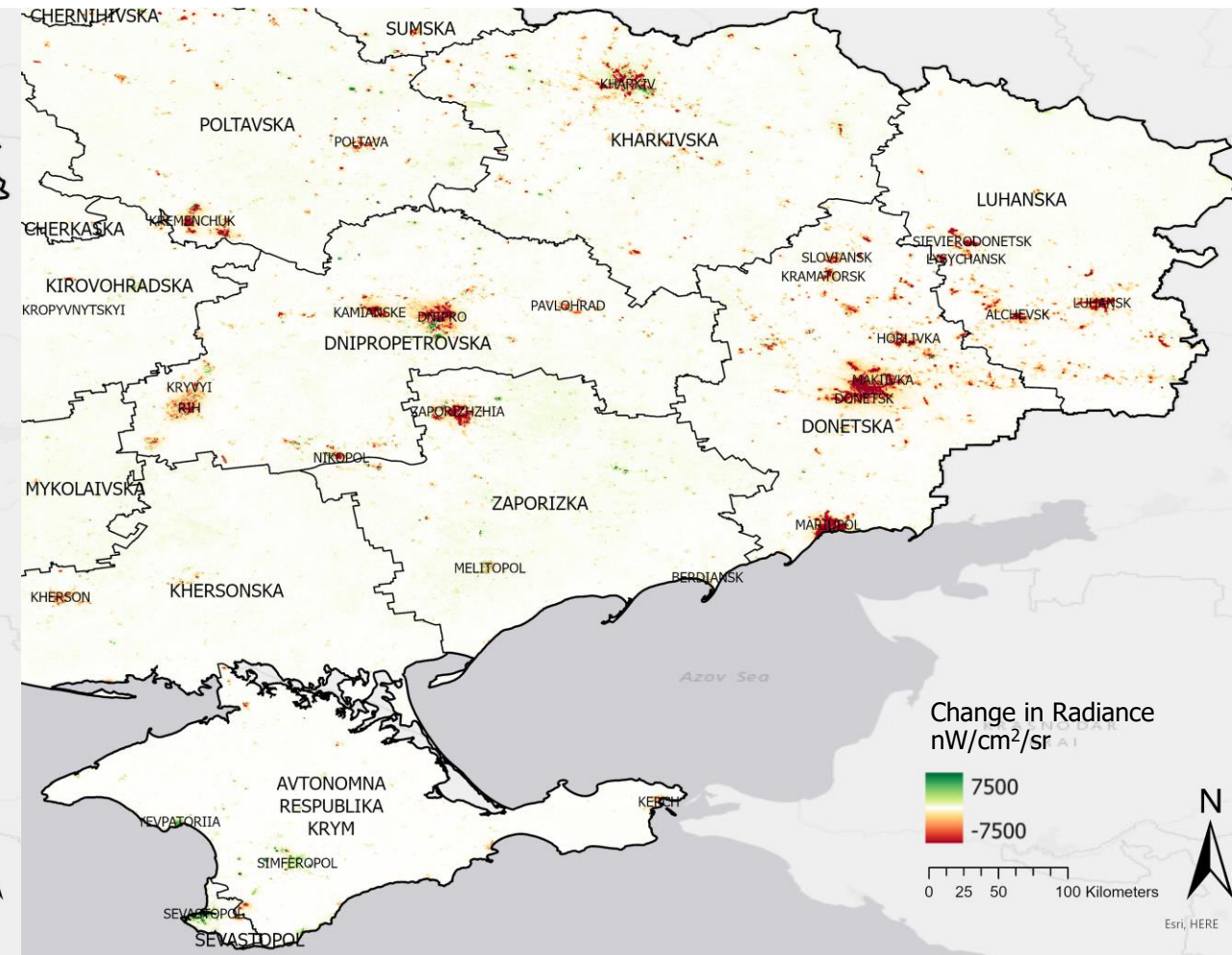
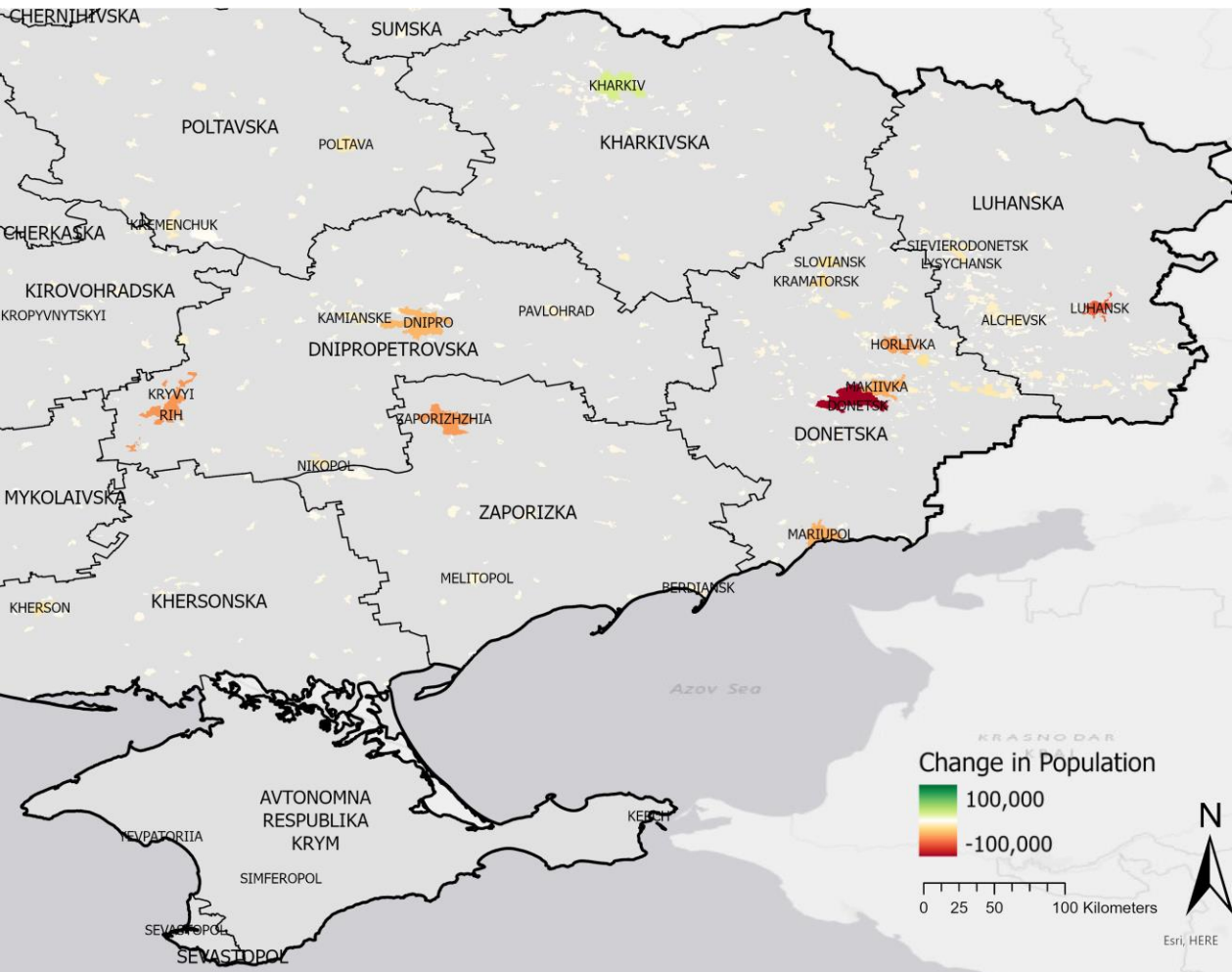
2013 to 2014



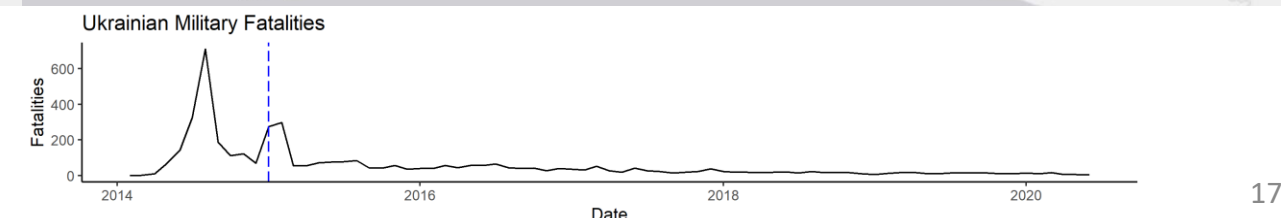


# Population Change

# Radiance Change

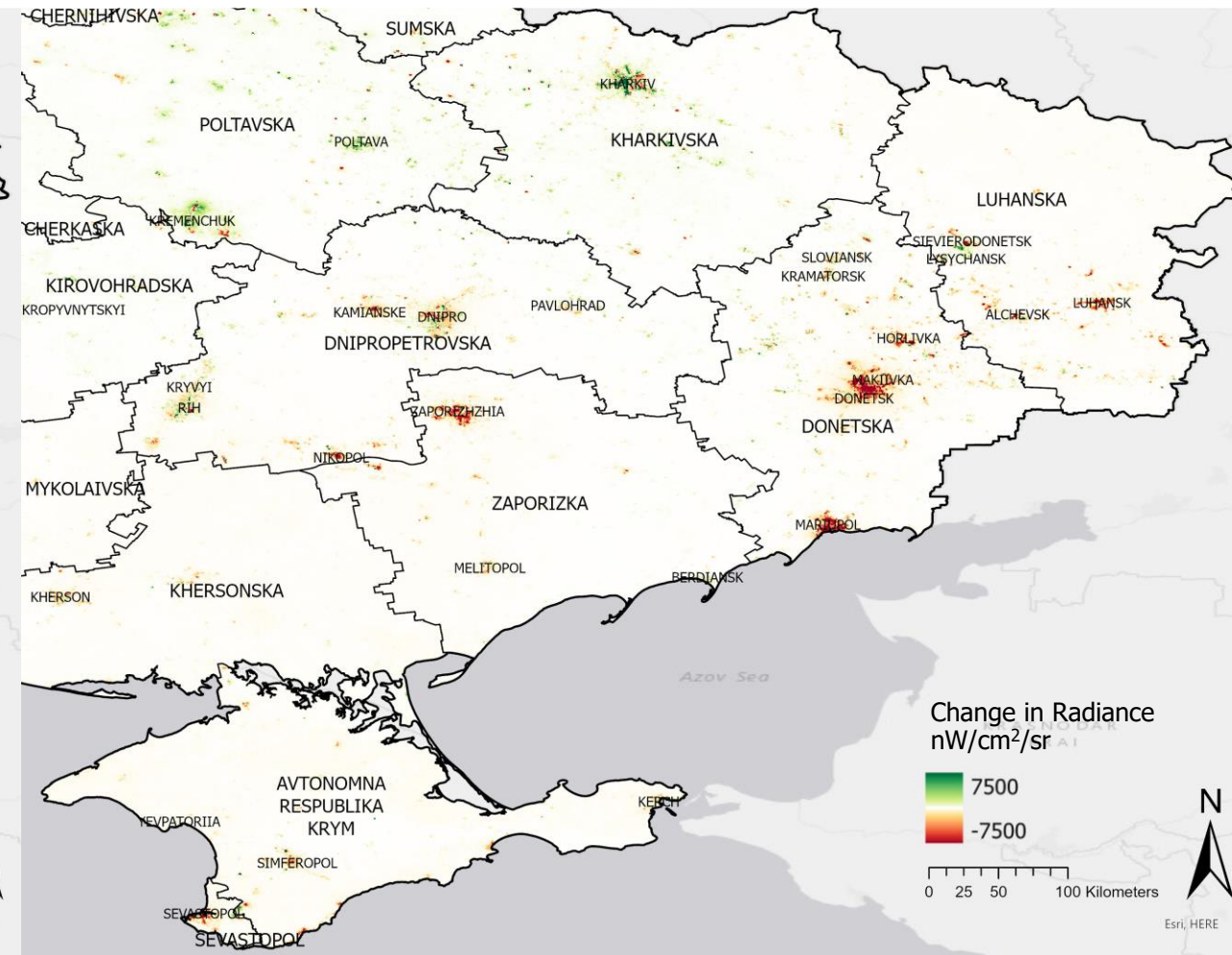
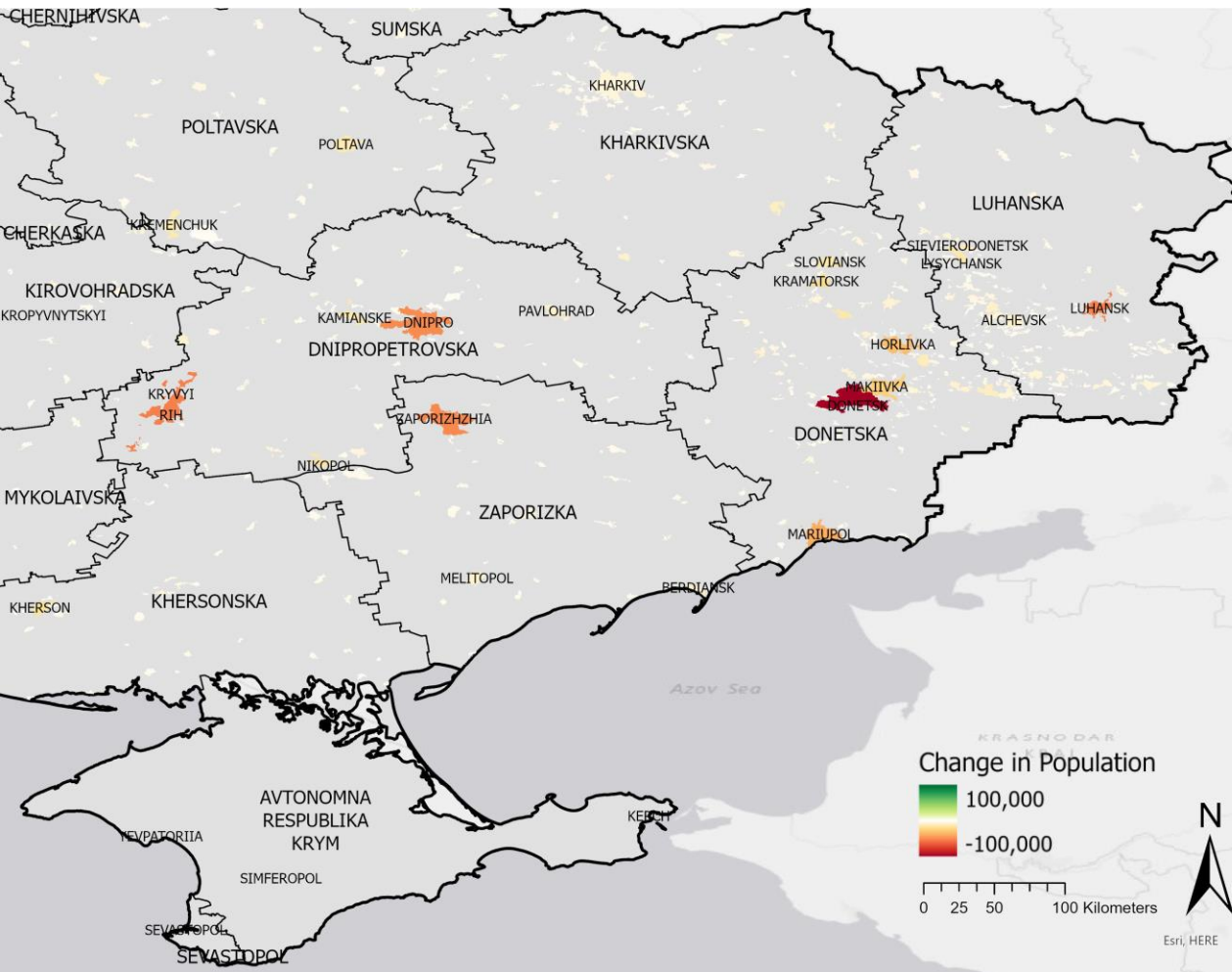


2014 to 2015

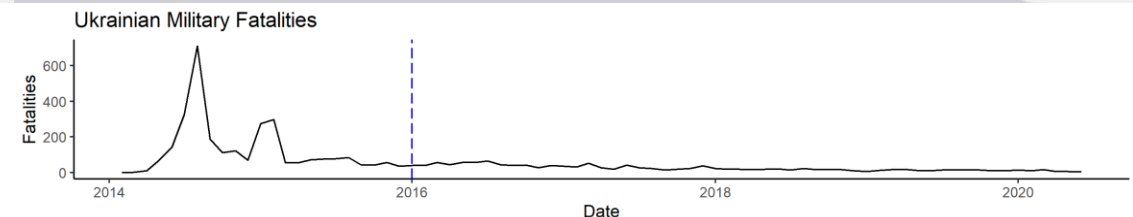


# Population Change

# Radiance Change

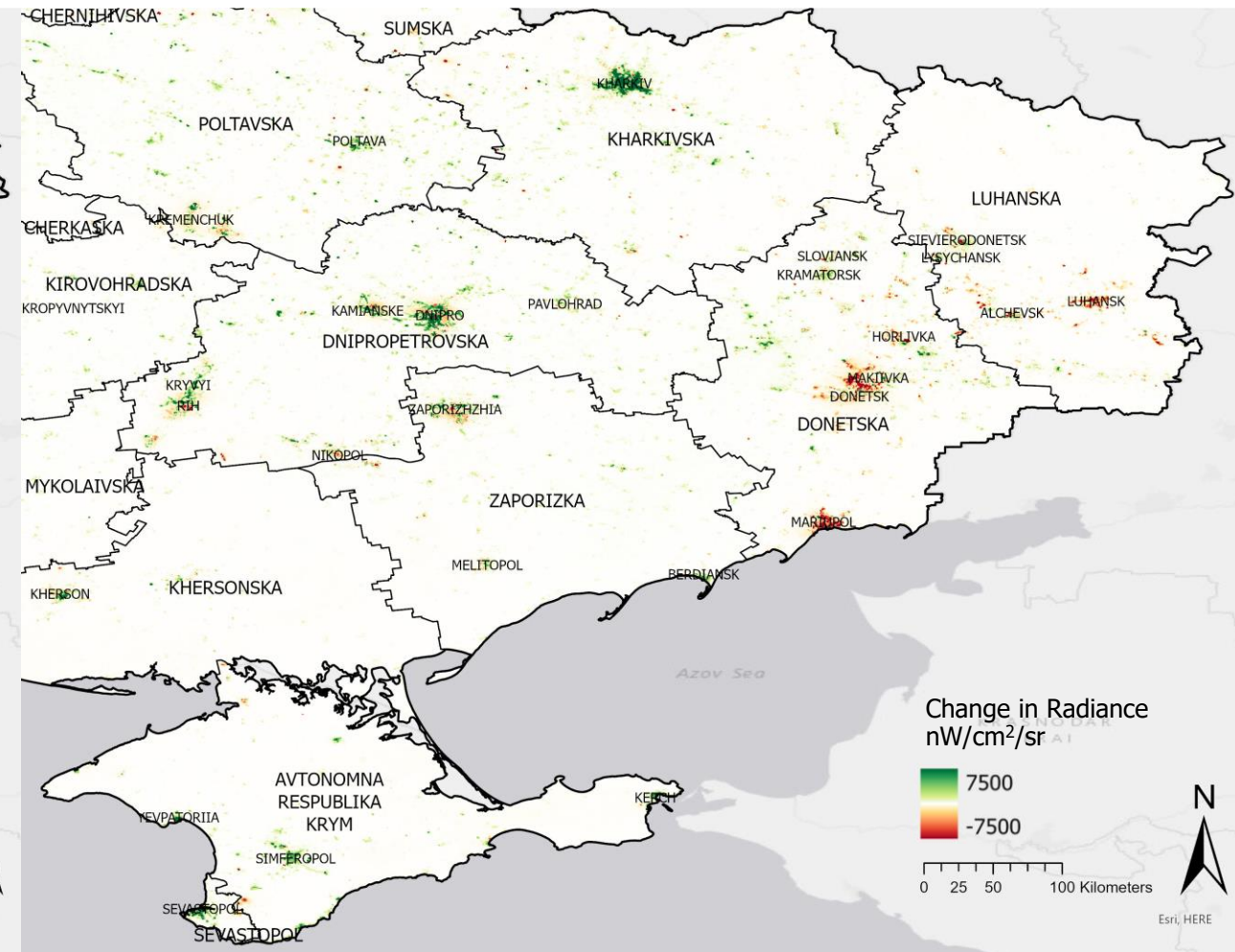
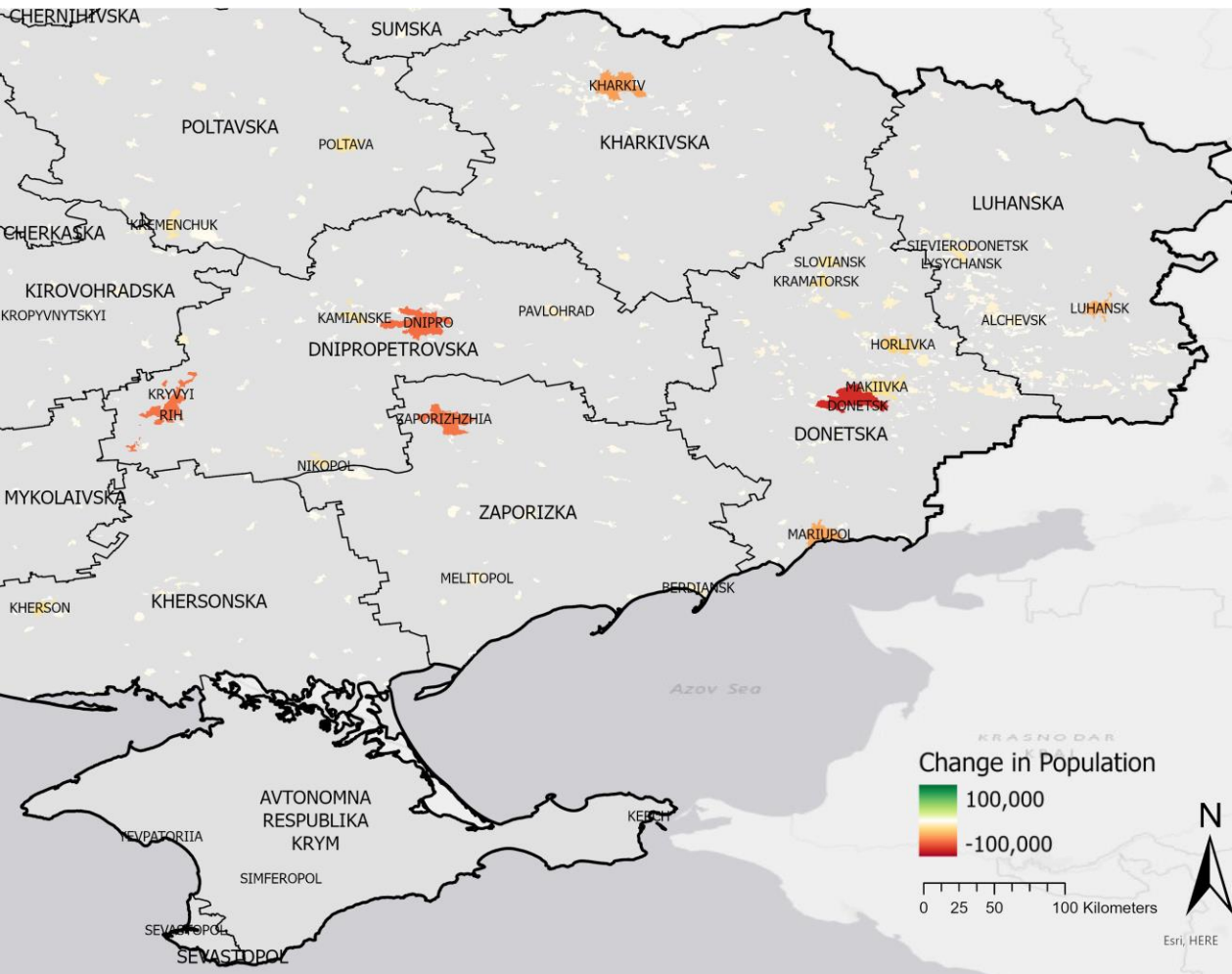


2014 to 2016

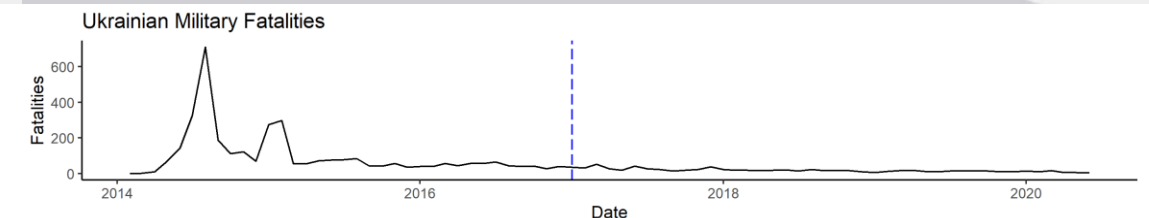


# Population Change

# Radiance Change

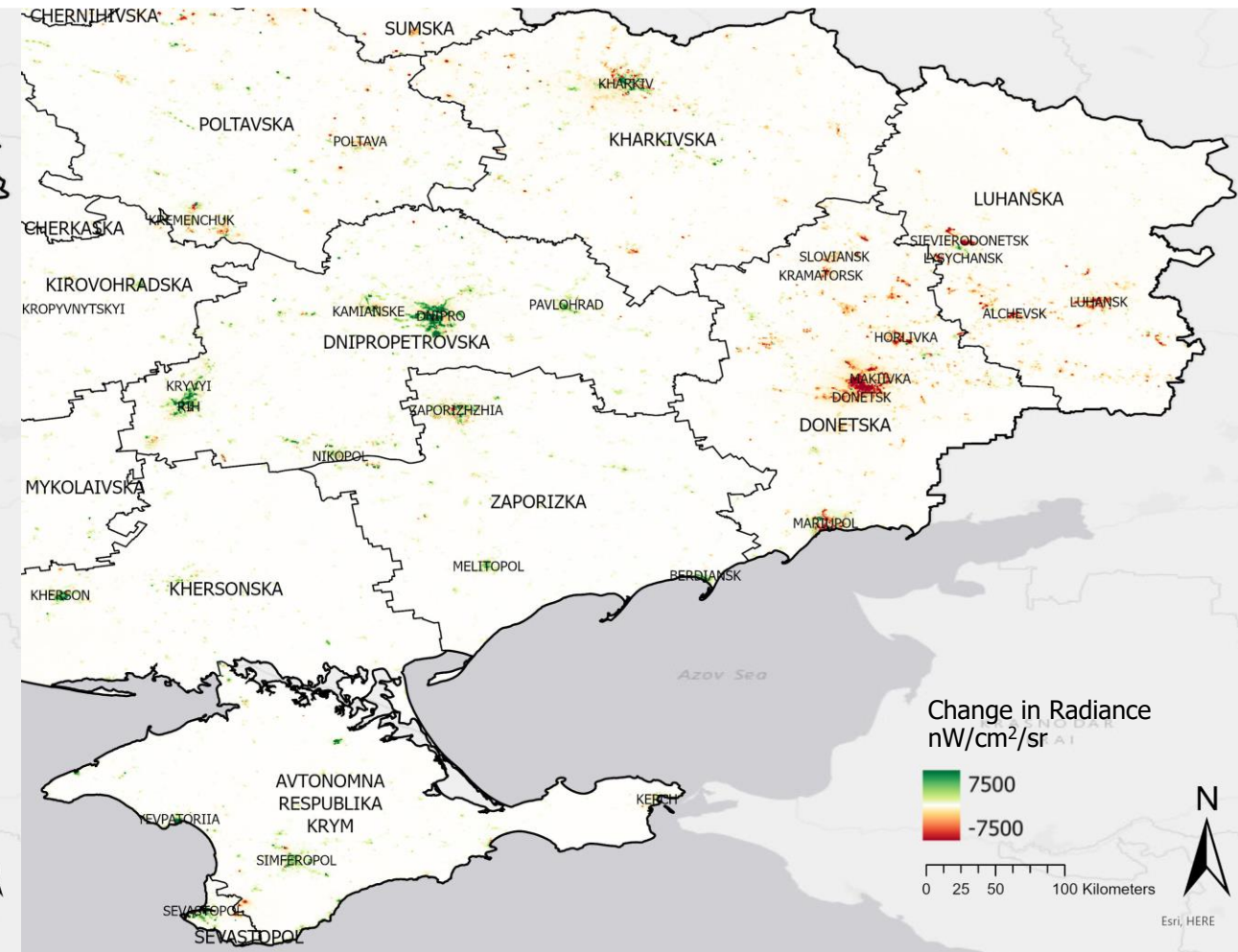
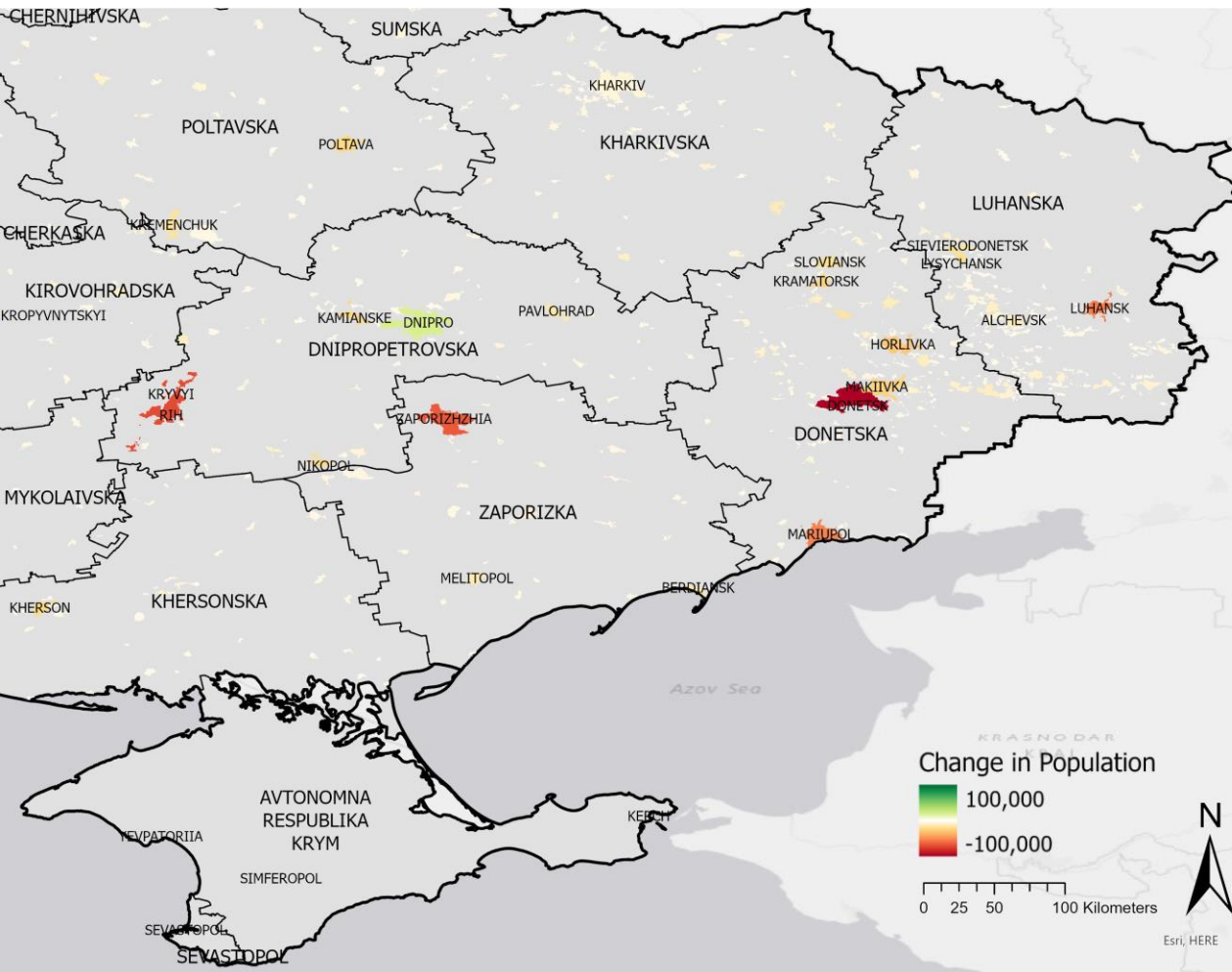


2014 to 2017

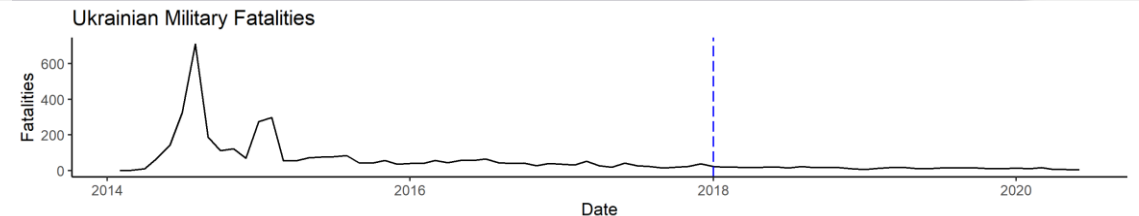


# Population Change

# Radiance Change

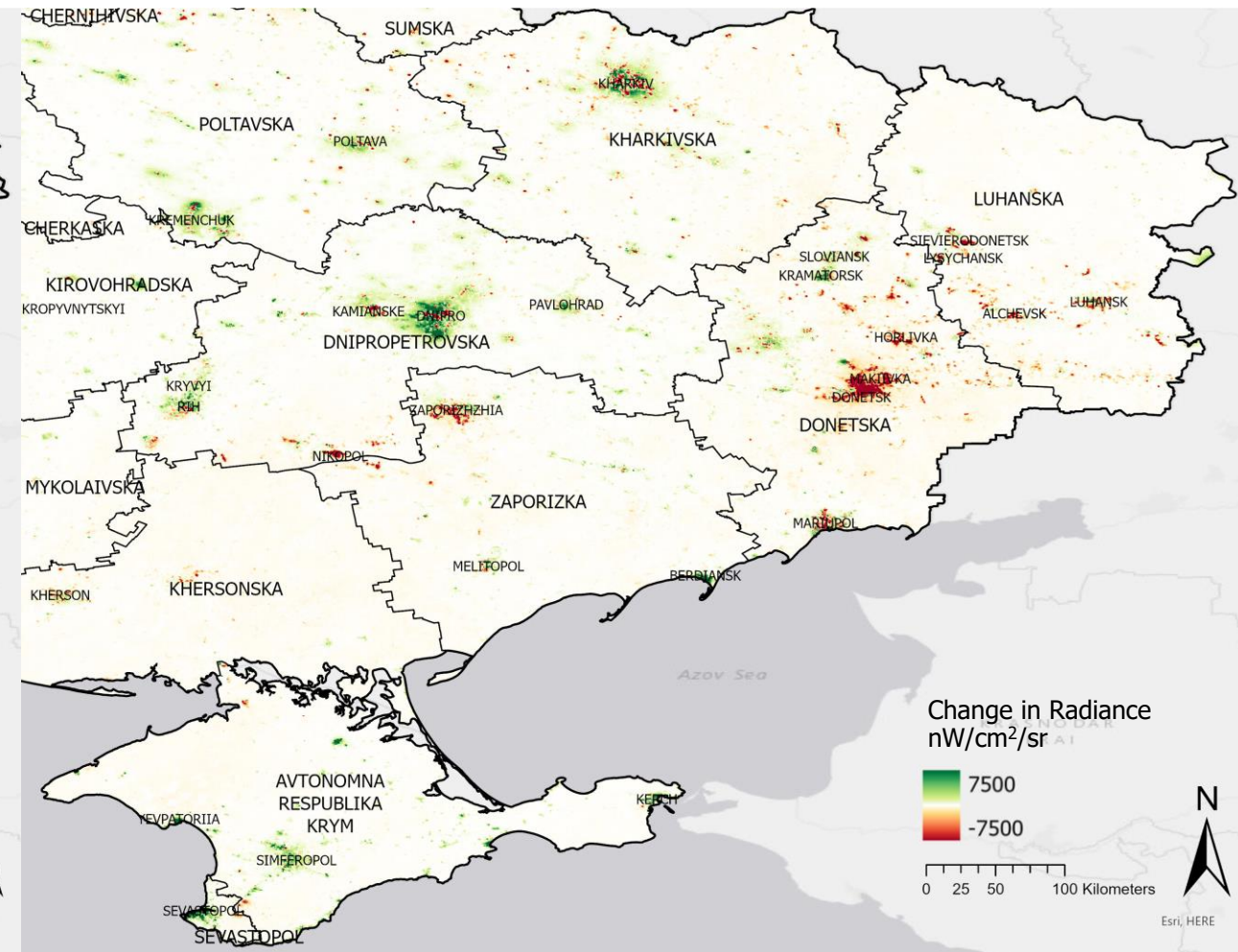
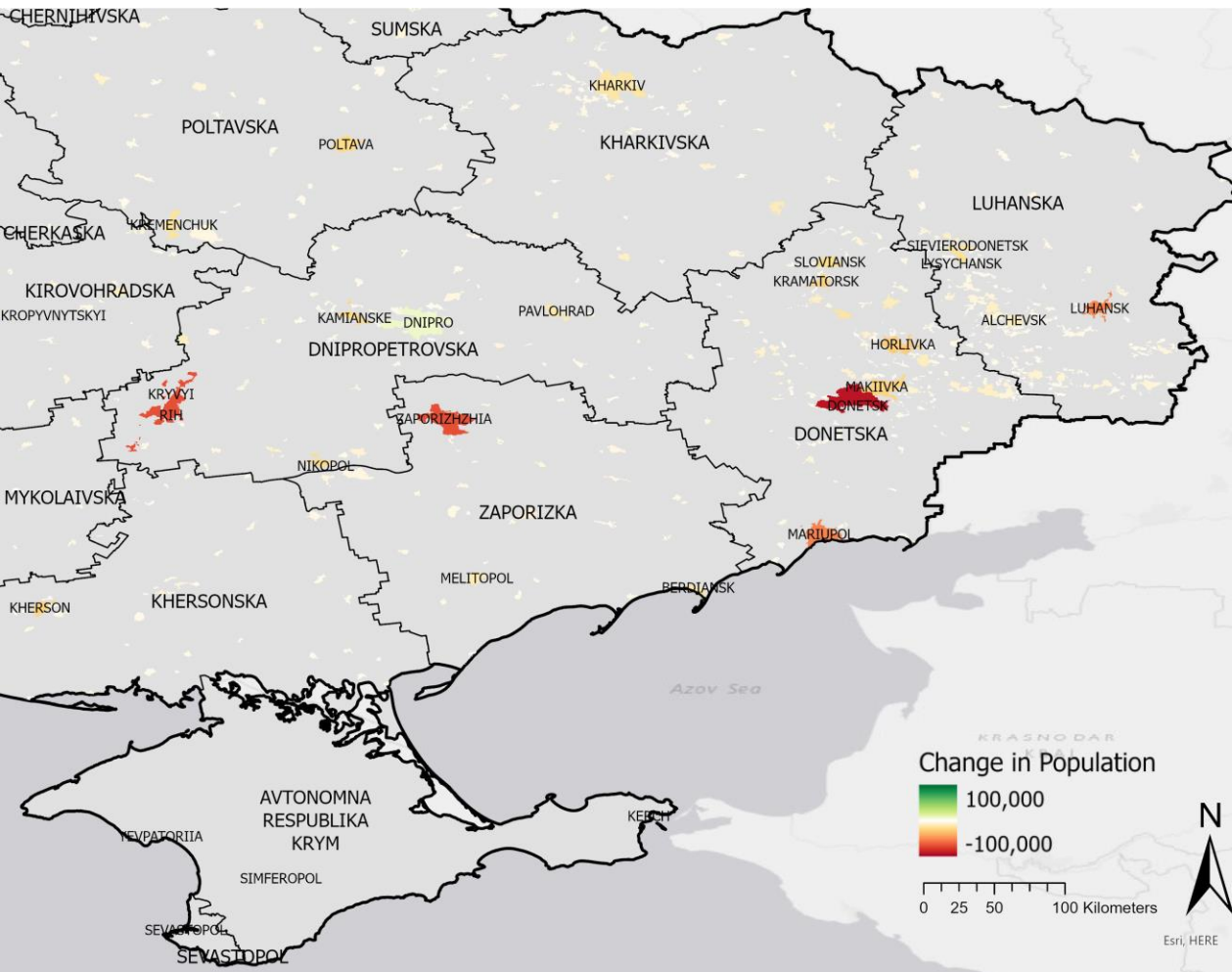


2014 to 2018

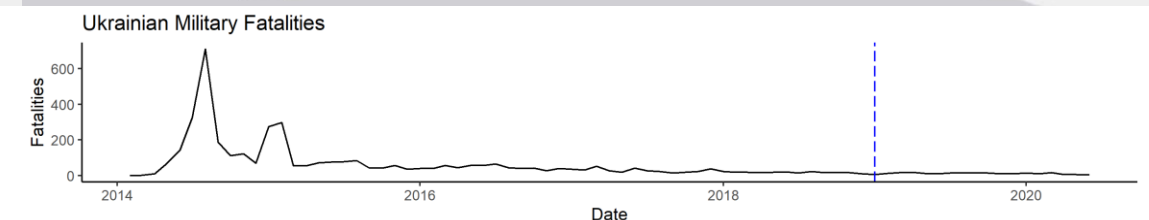


# Population Change

# Radiance Change

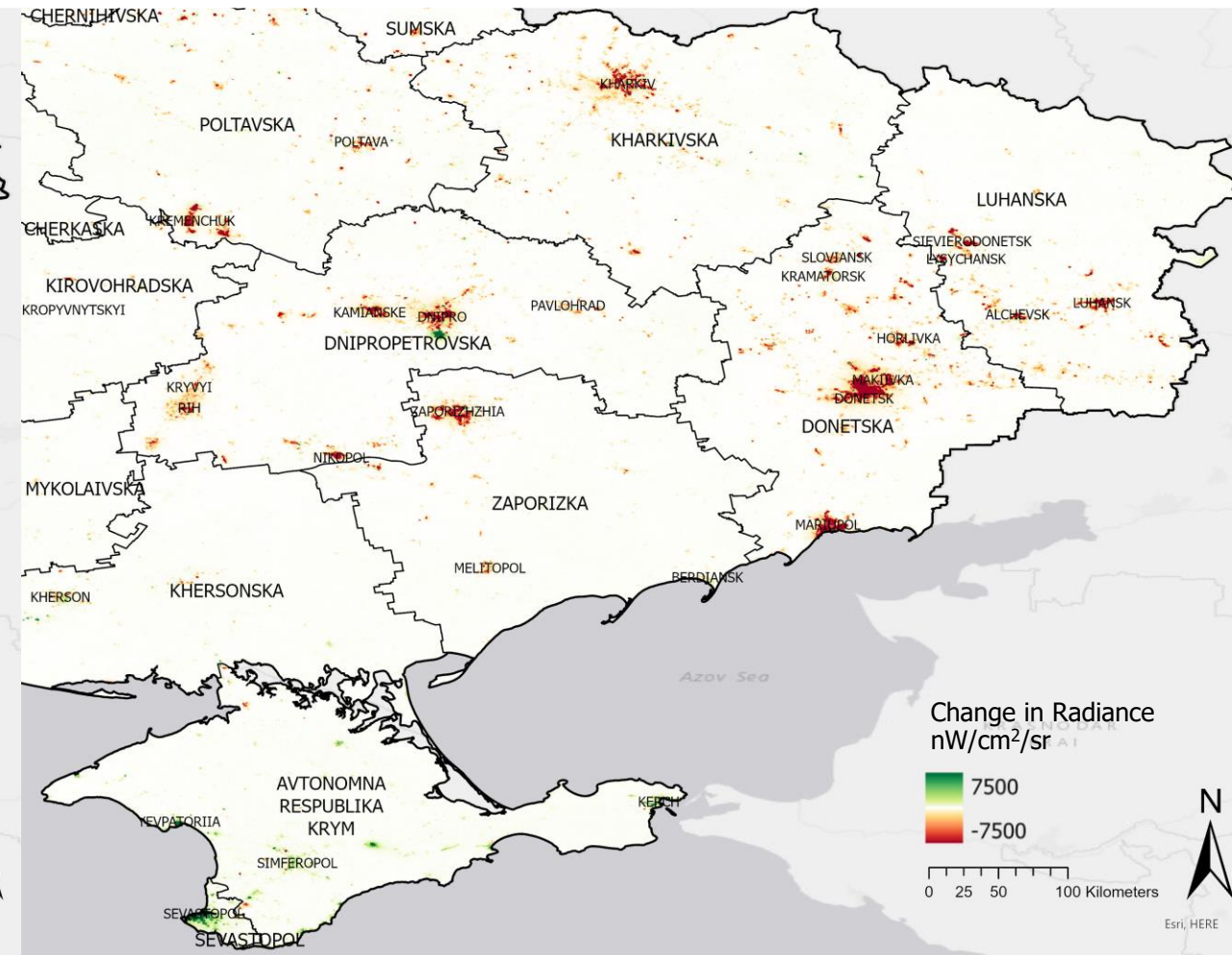
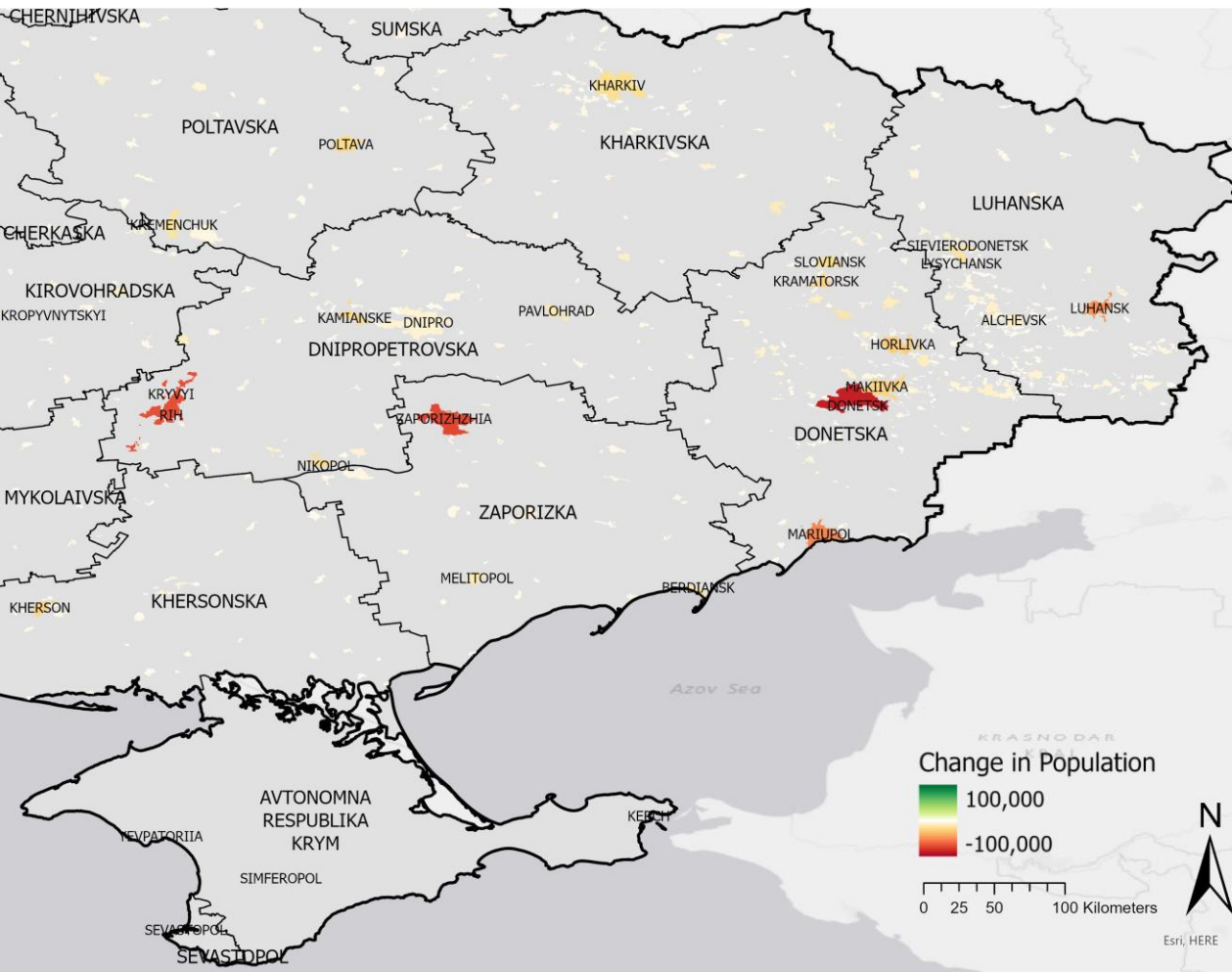


2014 to 2019

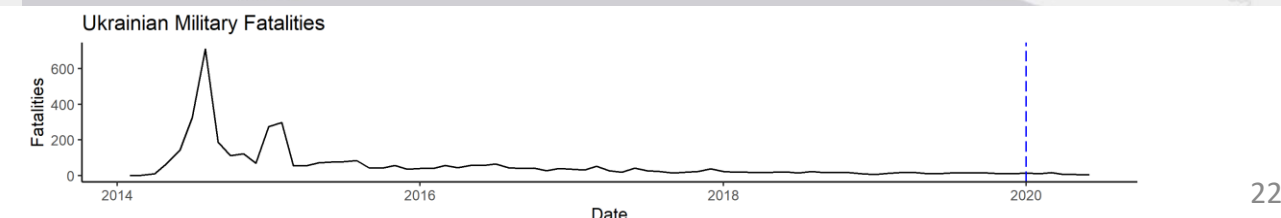


# Population Change

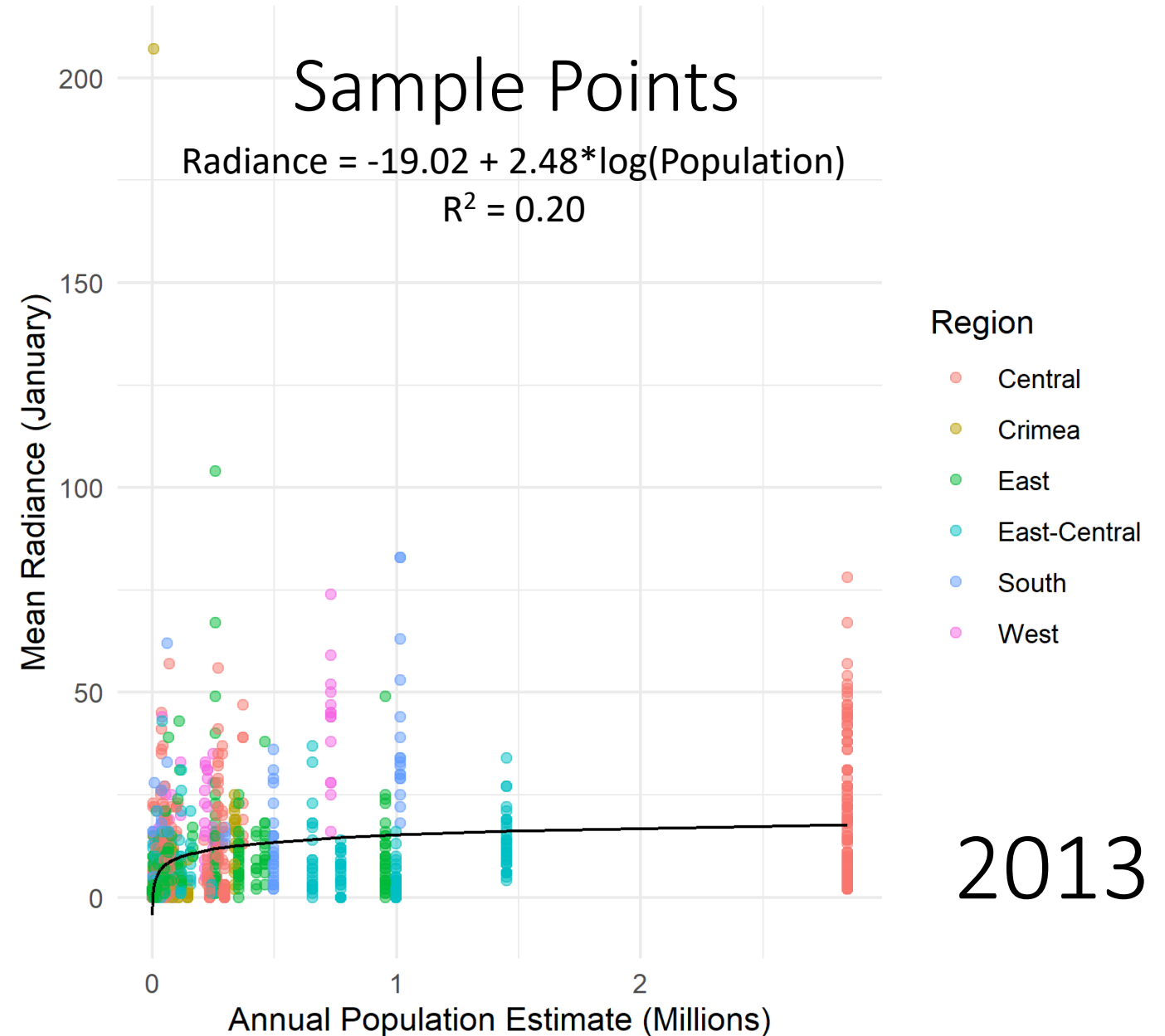
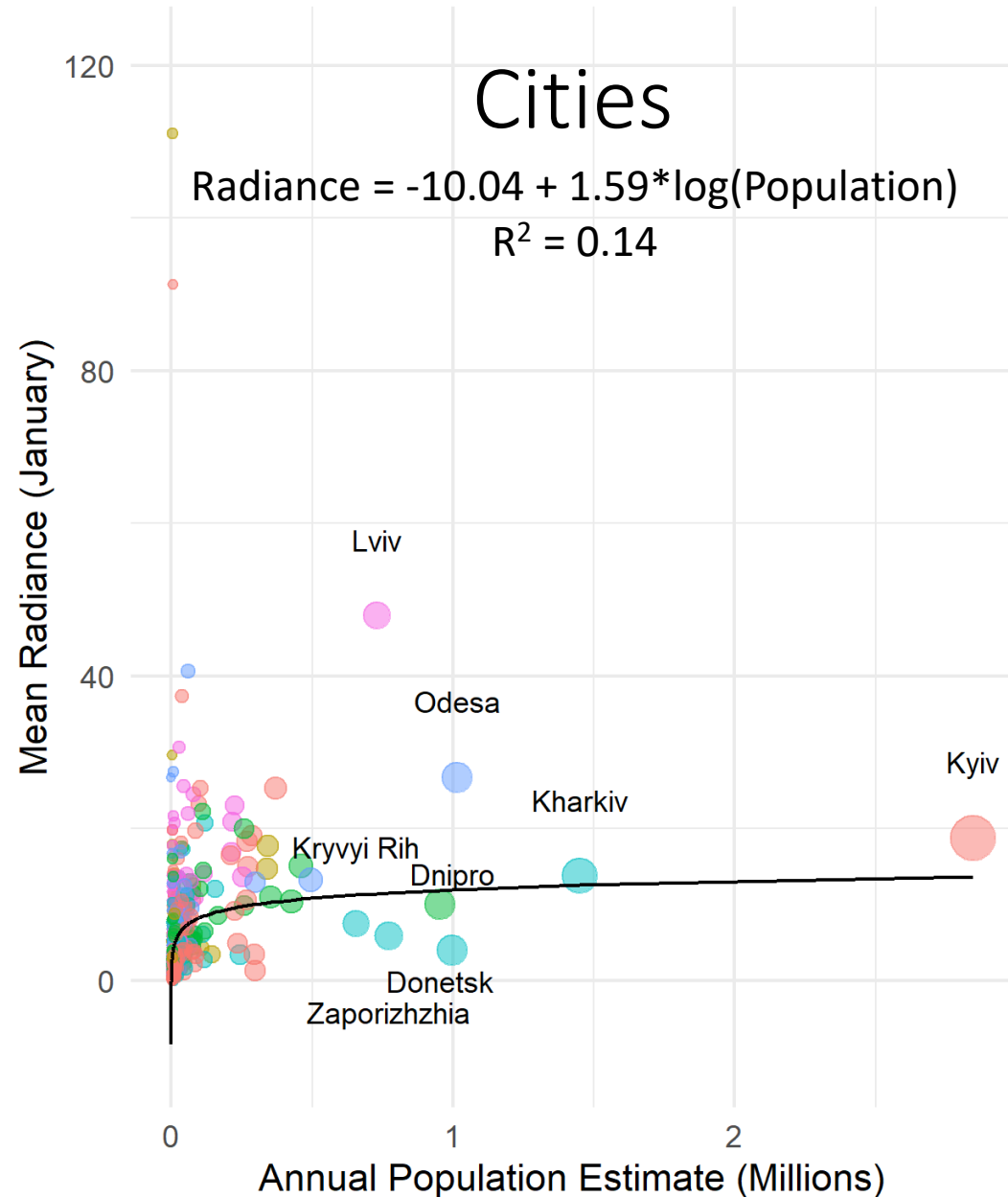
# Radiance Change



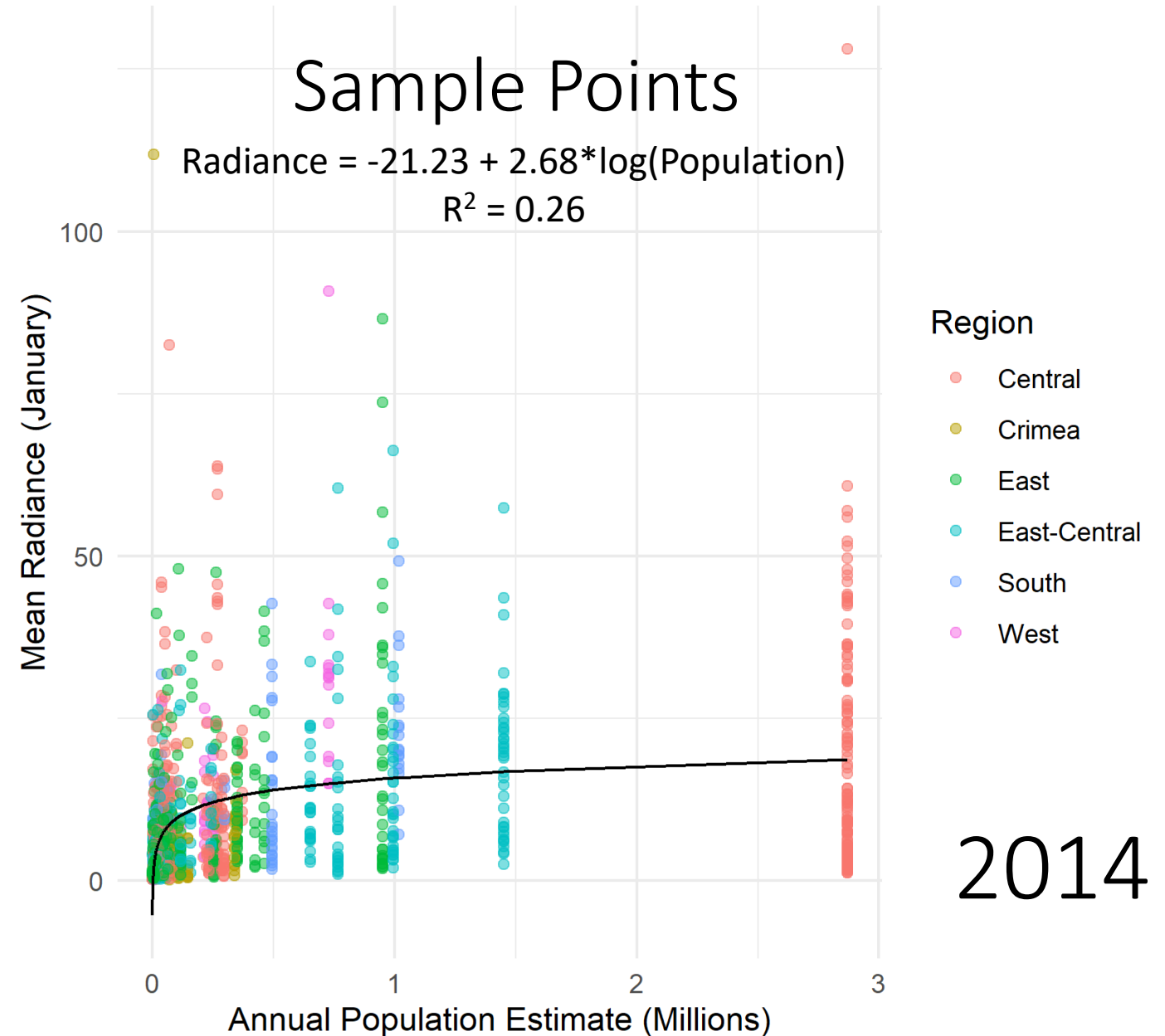
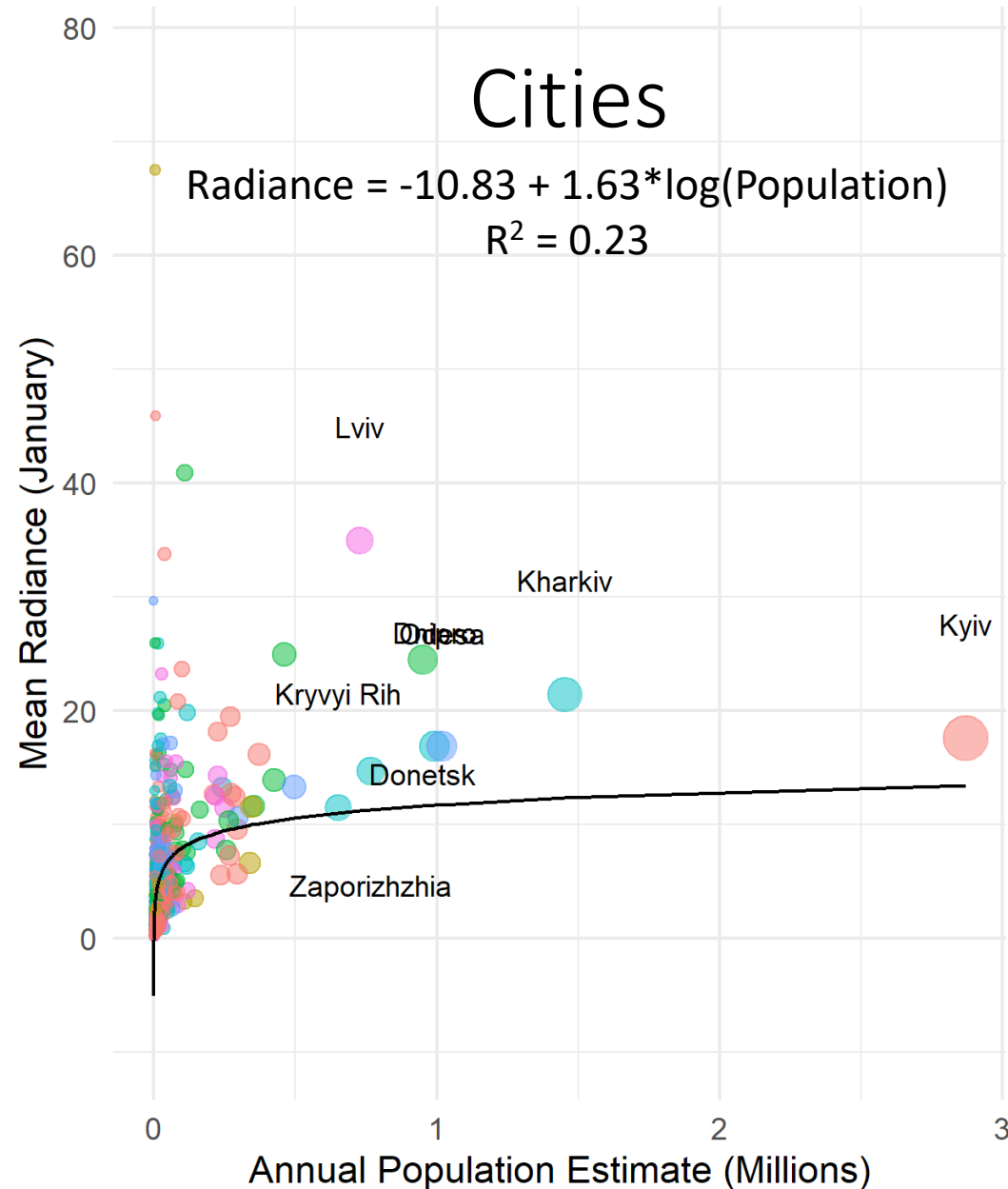
2014 to 2020



# Linear Model: log(Population) & Mean Radiance

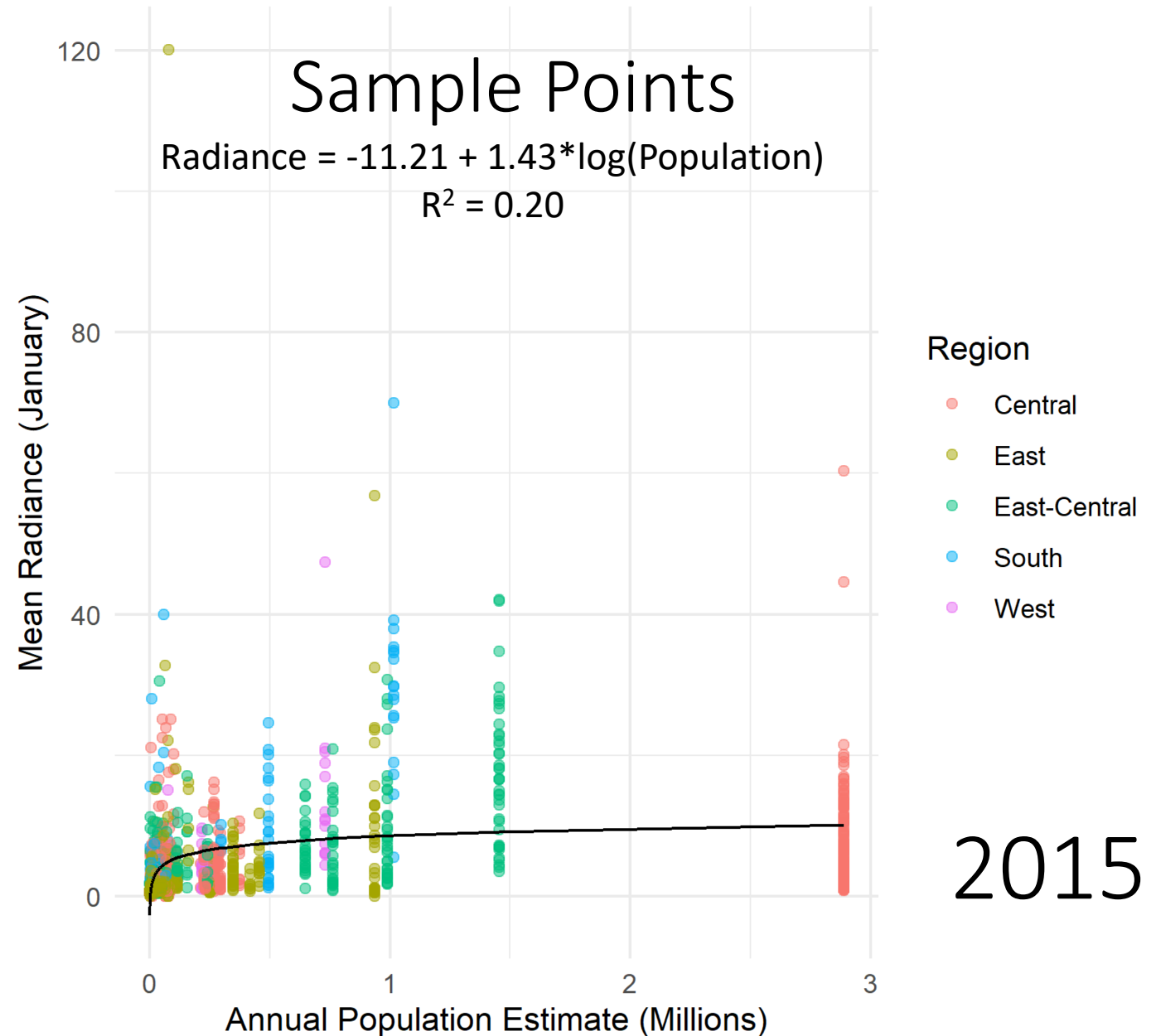
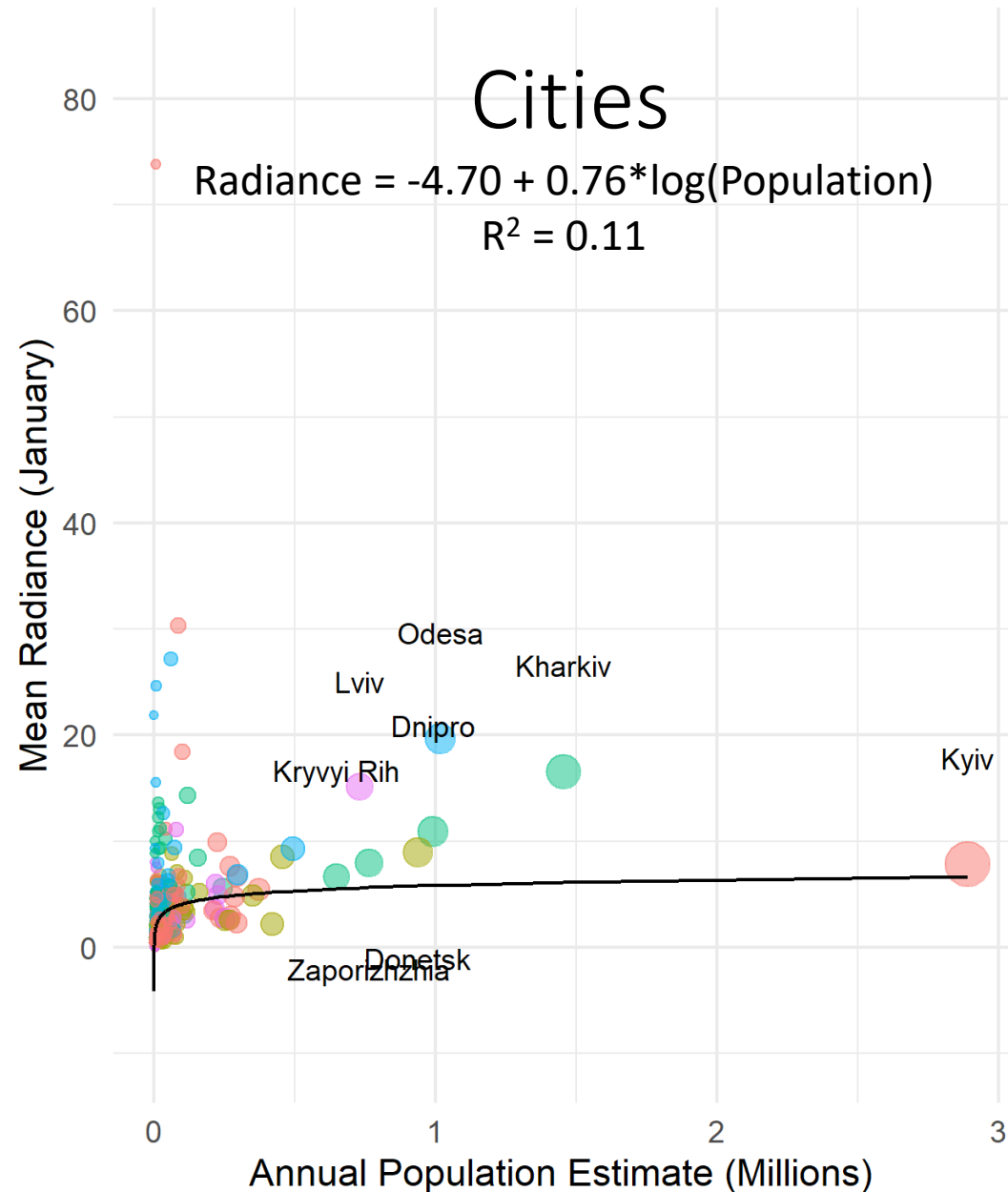


# Linear Model: log(Population) & Mean Radiance

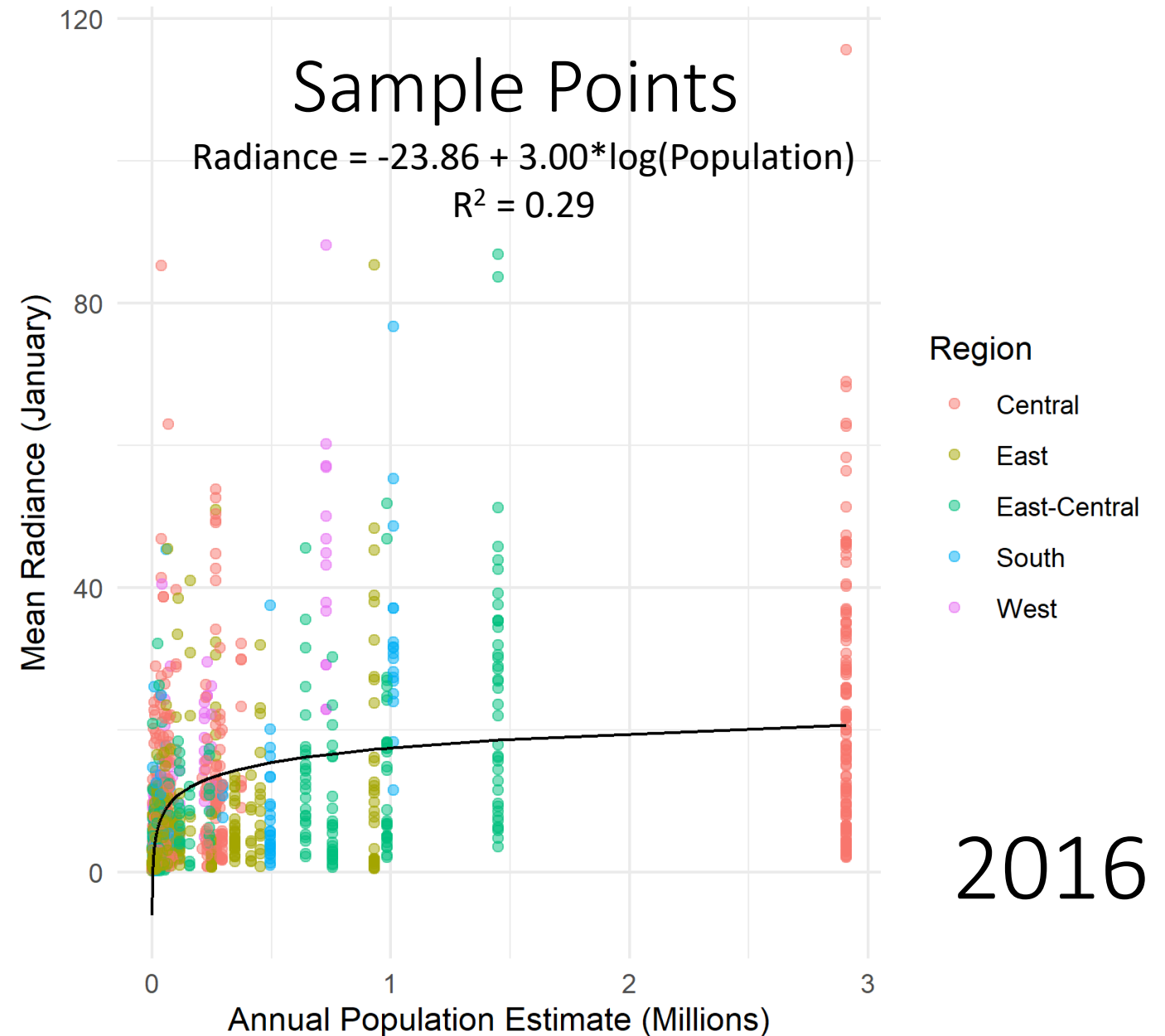
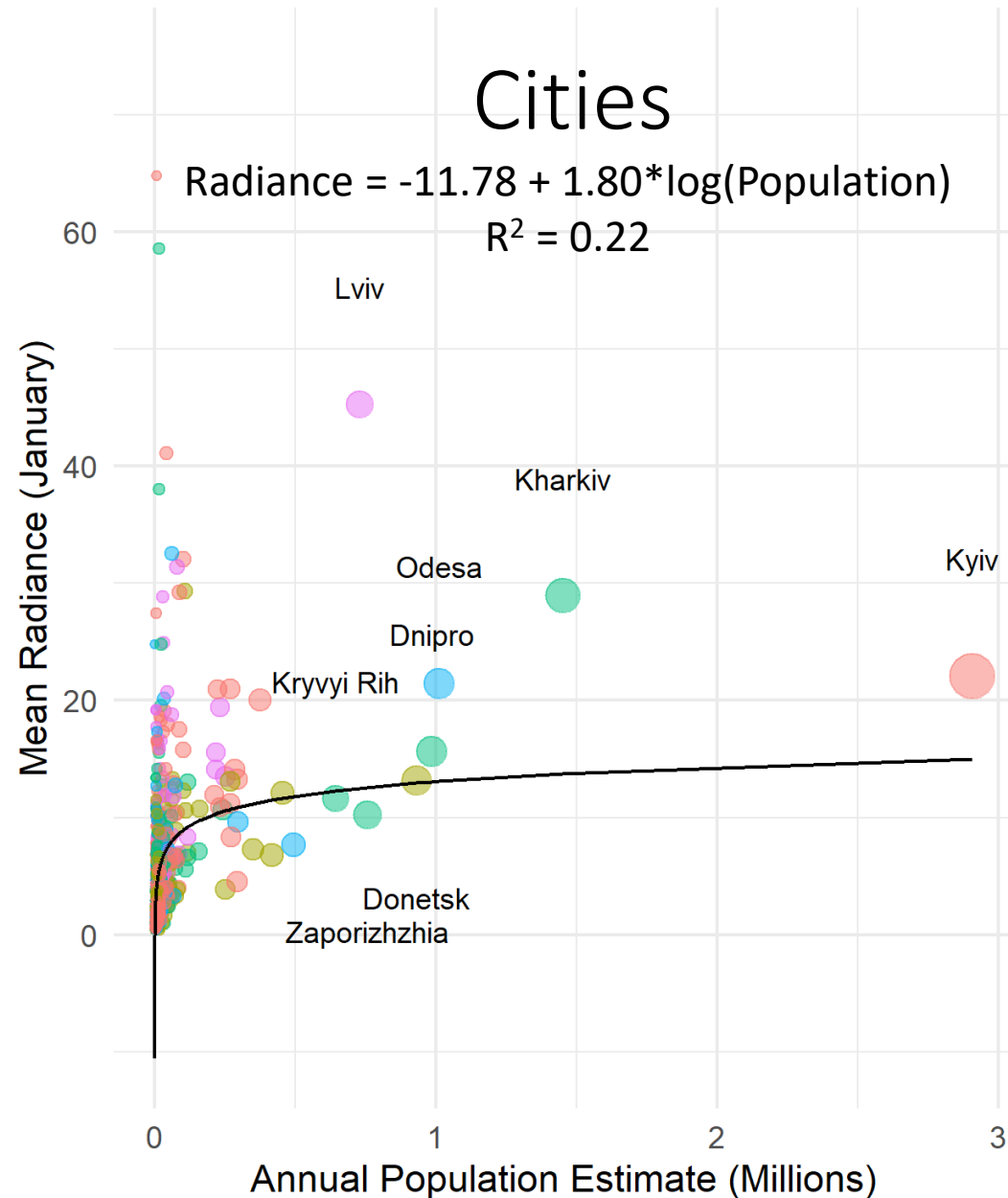




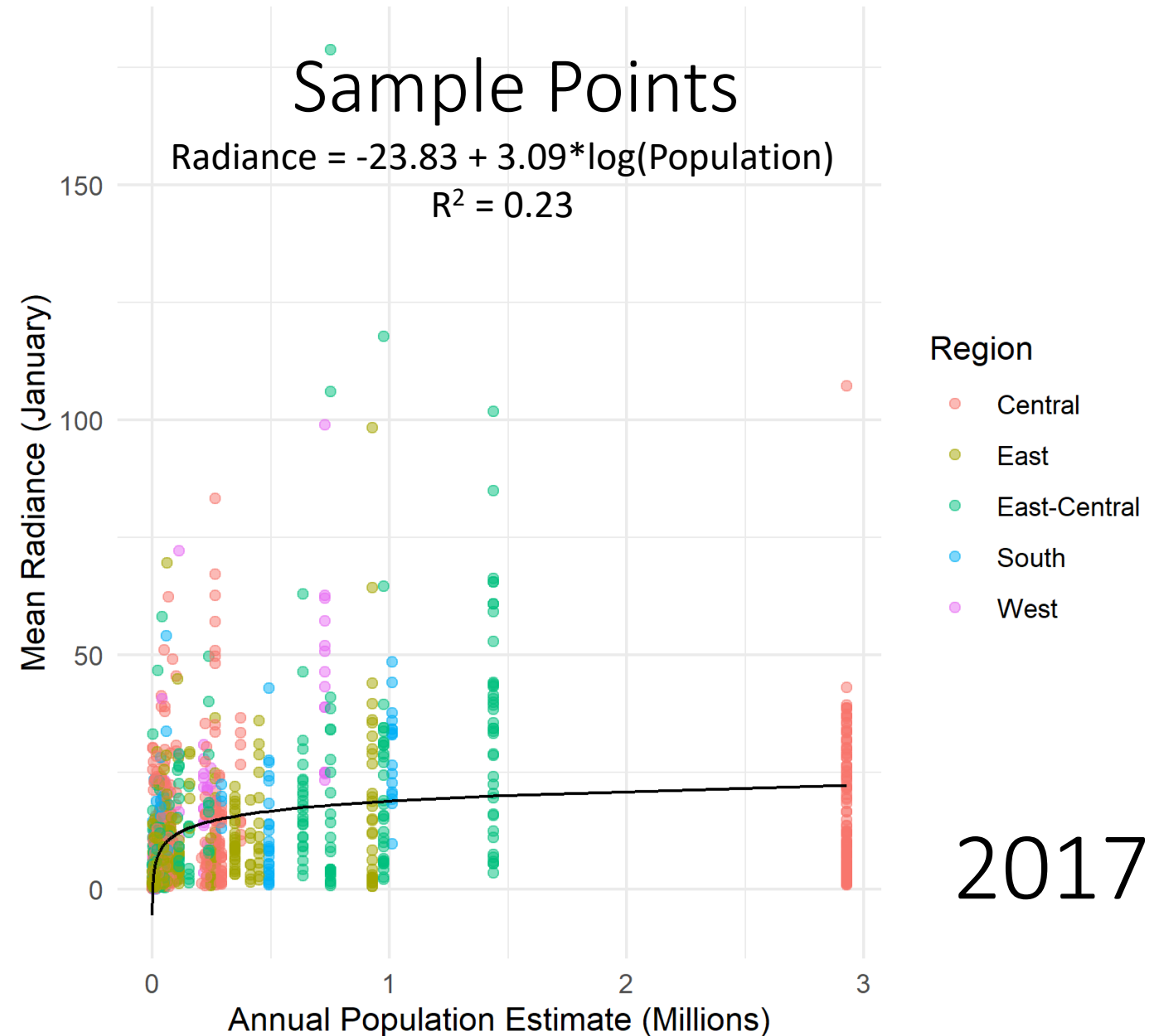
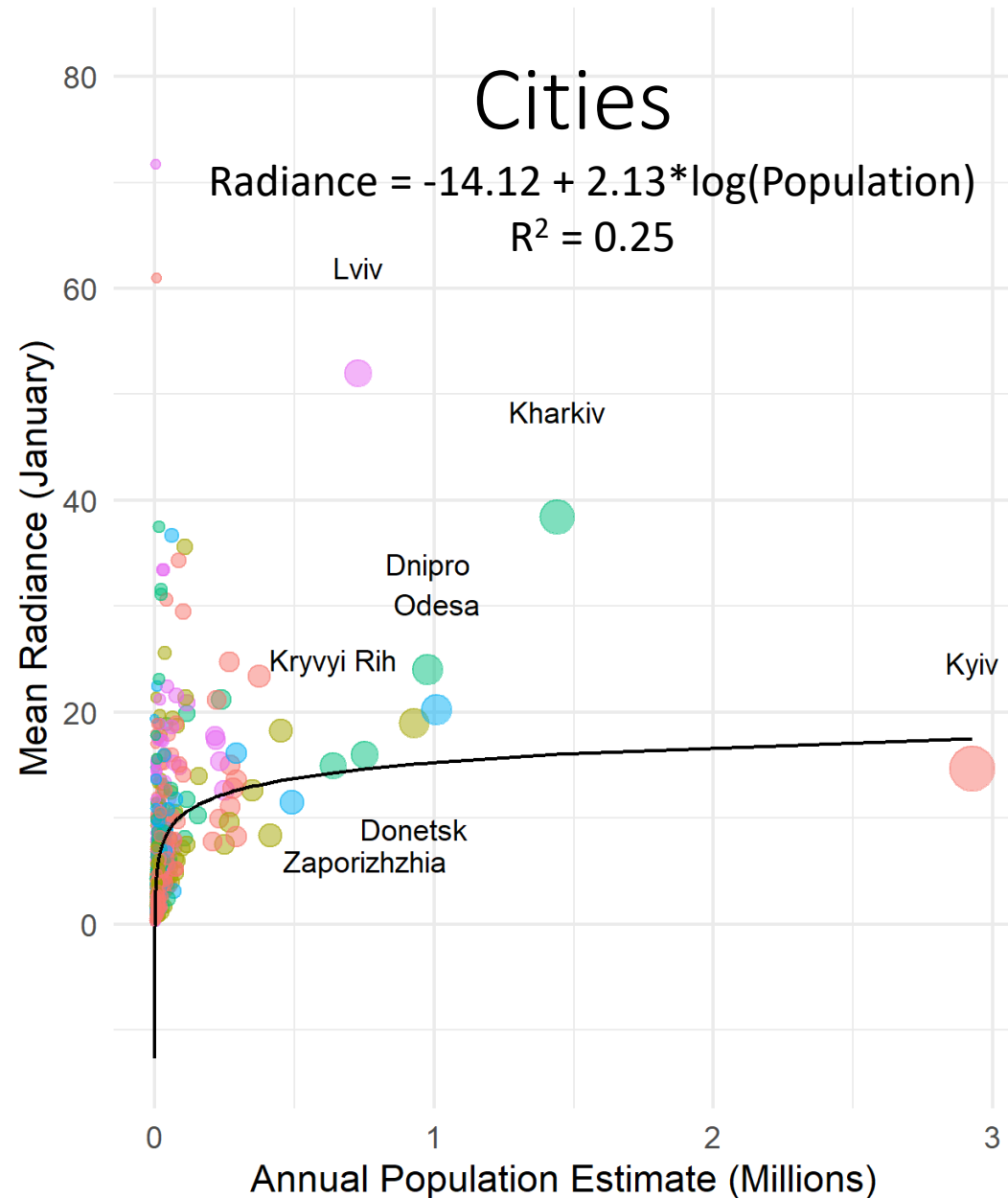
# Linear Model: log(Population) & Mean Radiance



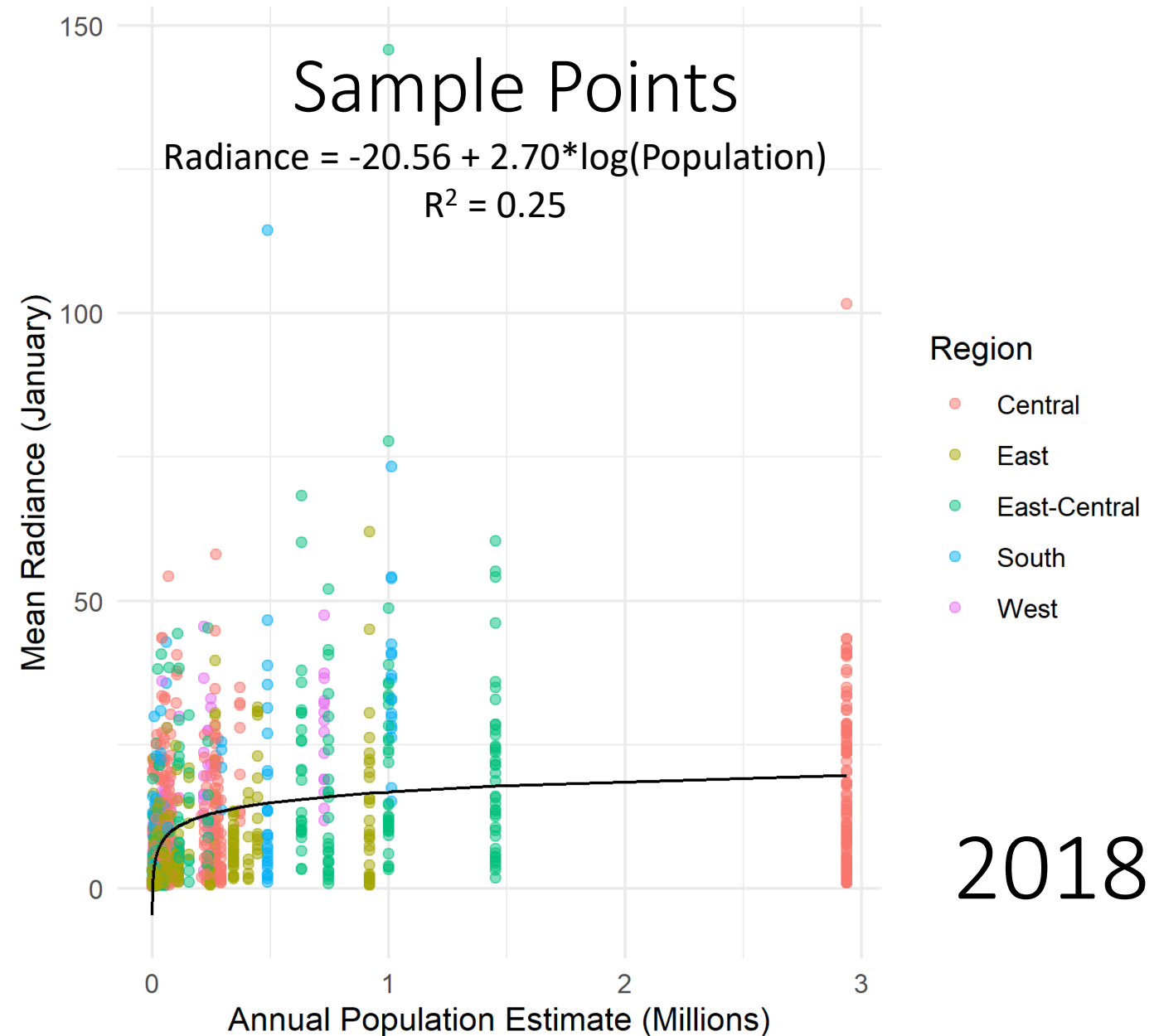
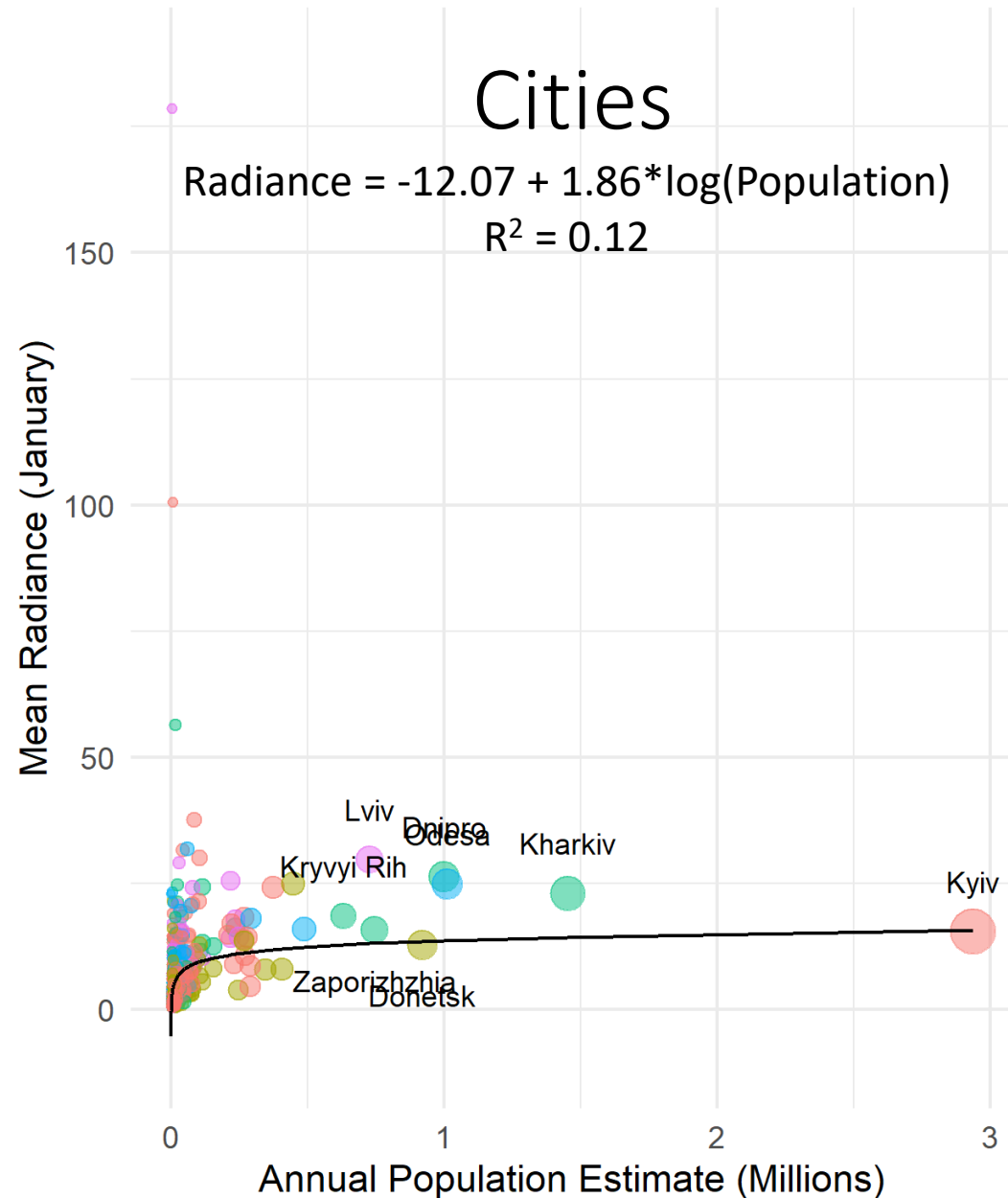
# Linear Model: log(Population) & Mean Radiance



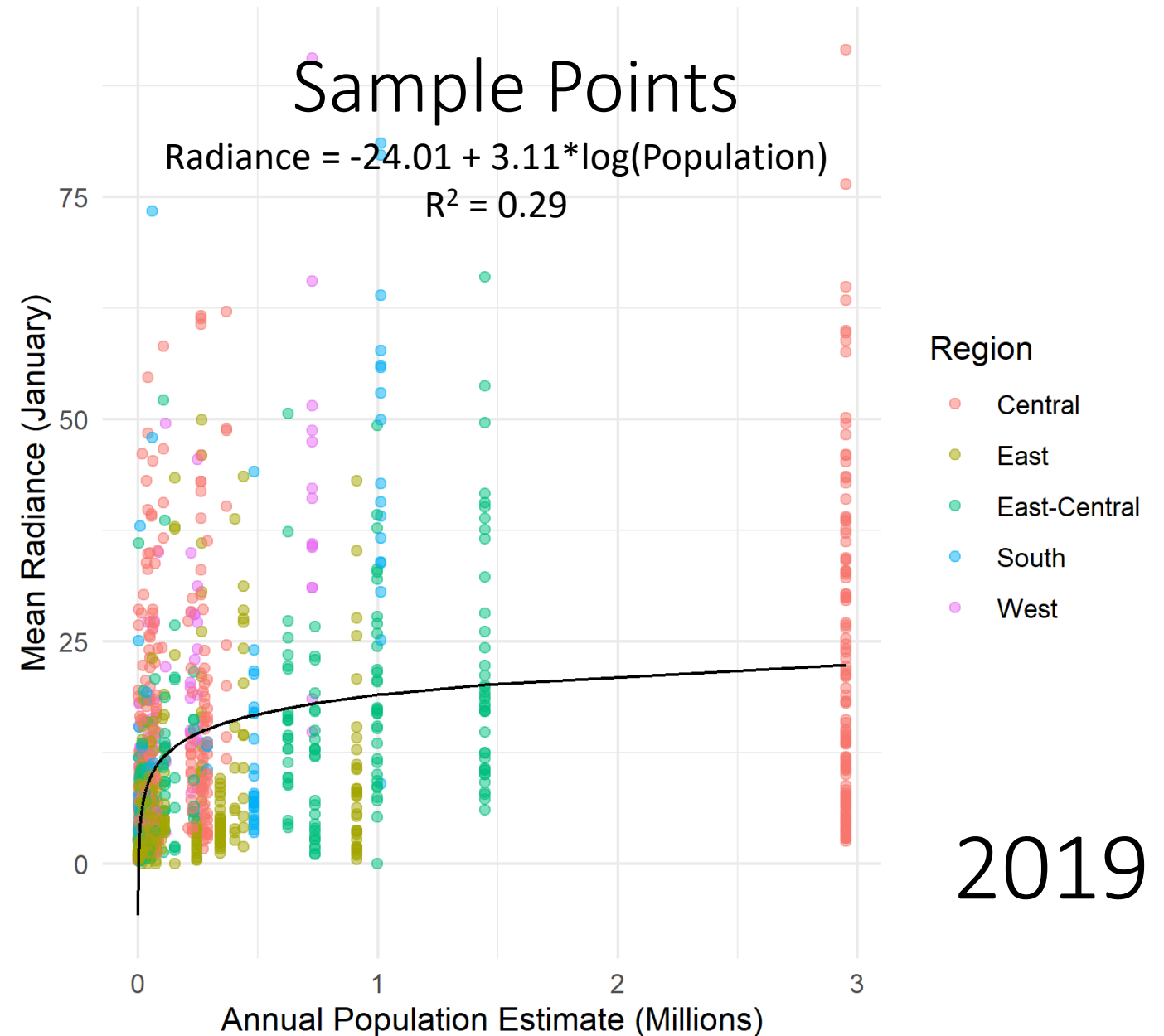
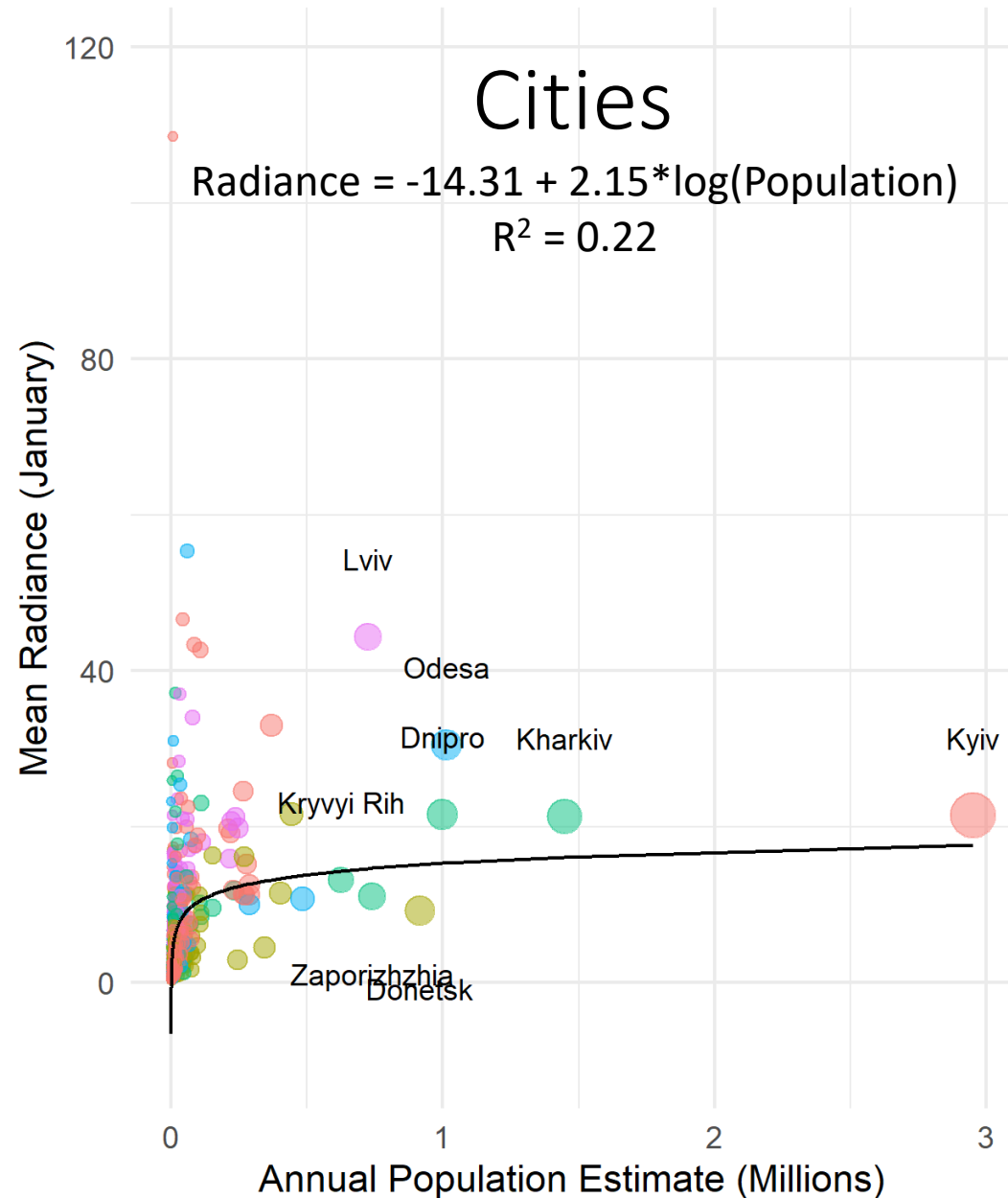
# Linear Model: log(Population) & Mean Radiance



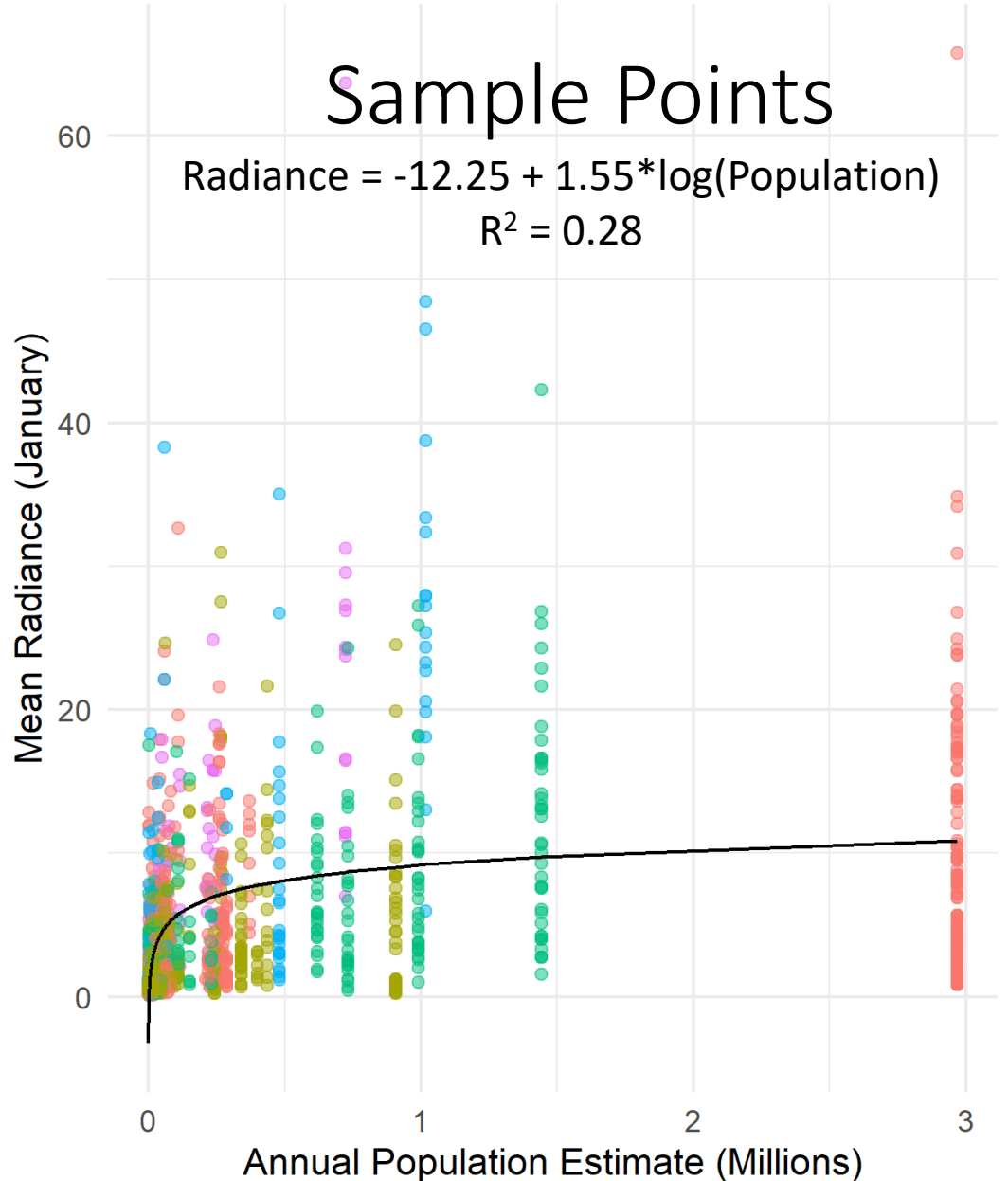
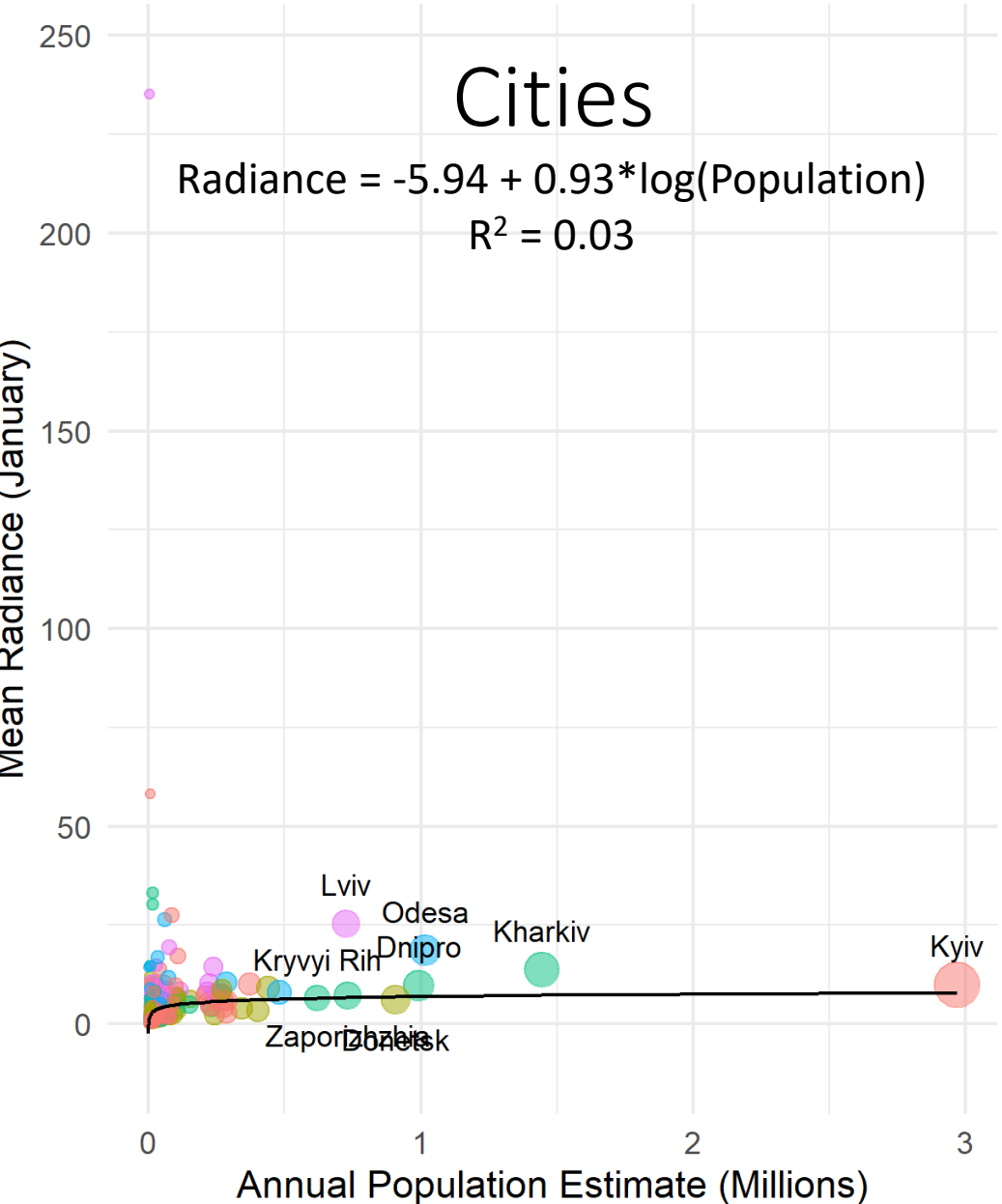
# Linear Model: log(Population) & Mean Radiance



# Linear Model: log(Population) & Mean Radiance



# Linear Model: log(Population) & Mean Radiance



2020

# Conclusion

- Nighttime lights do reflect changes consistent with recorded population shifts
- Other place definitions may be necessary for more accurate predictions
- Future research should consider population density, GDP, electricity prices, etc.
- The nighttime lights data could be useful to Ukraine researchers,
  - Especially in a user-friendly format

# Sources

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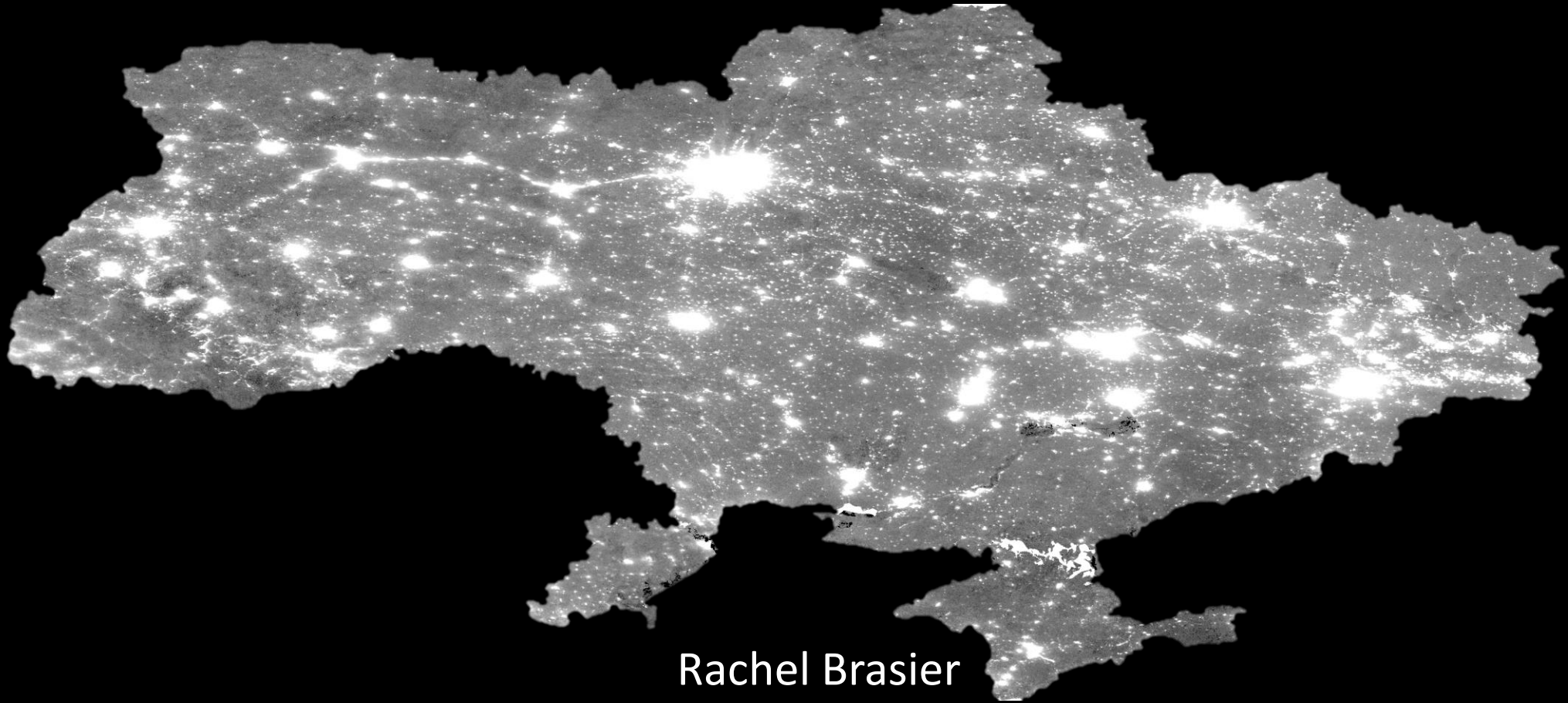
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# Nighttime Lights in the Donbas:

## Modeling Conflict Migration Patterns in Ukraine Using Satellite Imagery

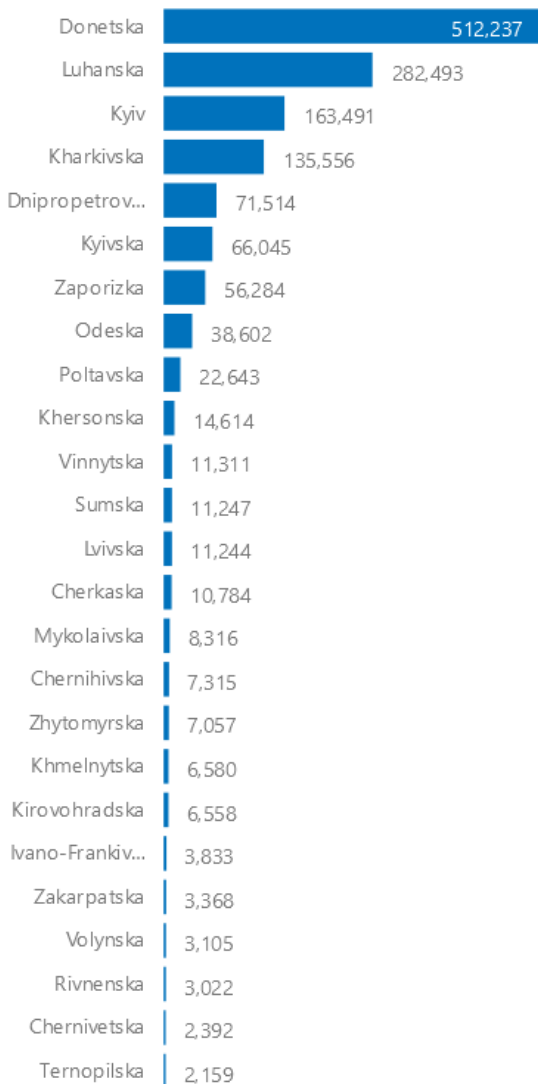


Rachel Brasier  
5 August 2021

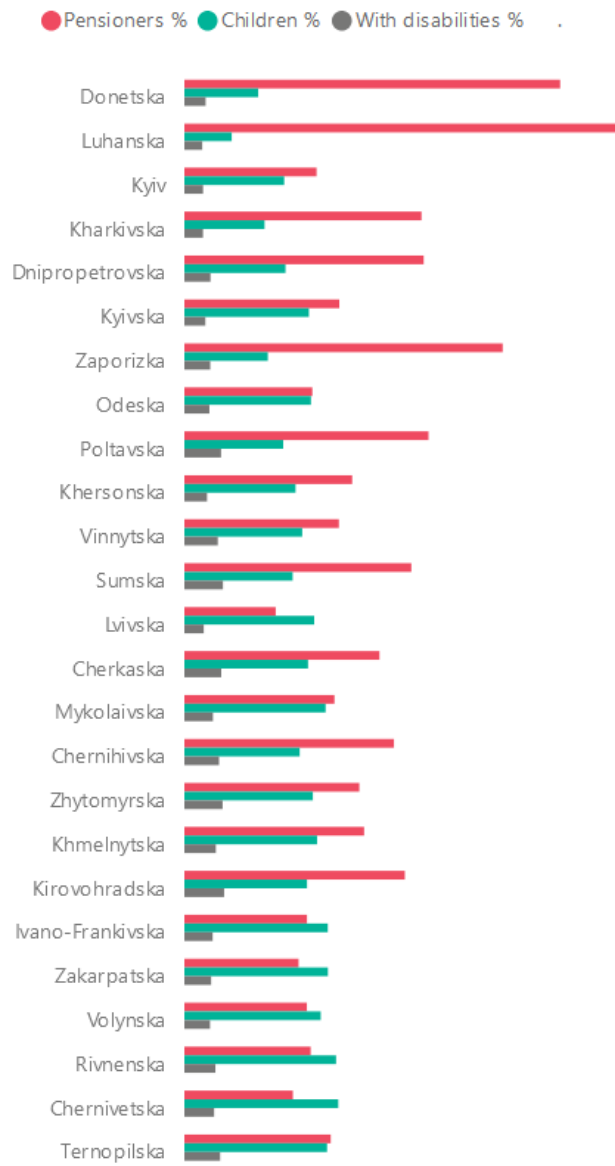
Source: Ministry of Social Policy (MoSP) / Last update: 05 March 2021

Registered IDPs in MoSP Database

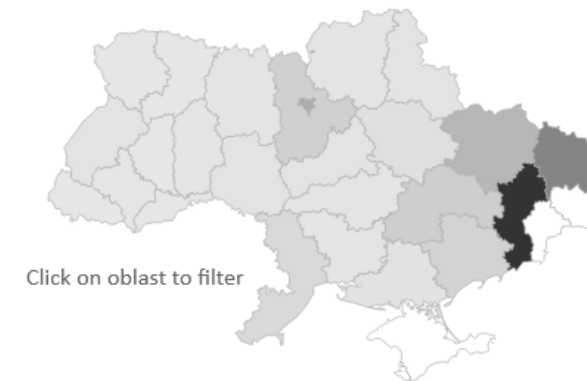
## Number of registered internally displaced persons (IDPs) by Oblast



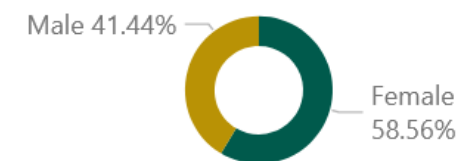
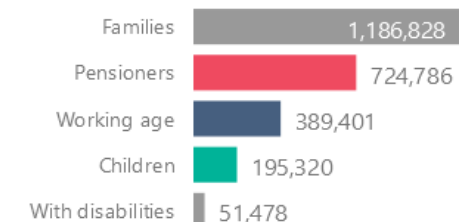
## IDPs by Category by Oblast



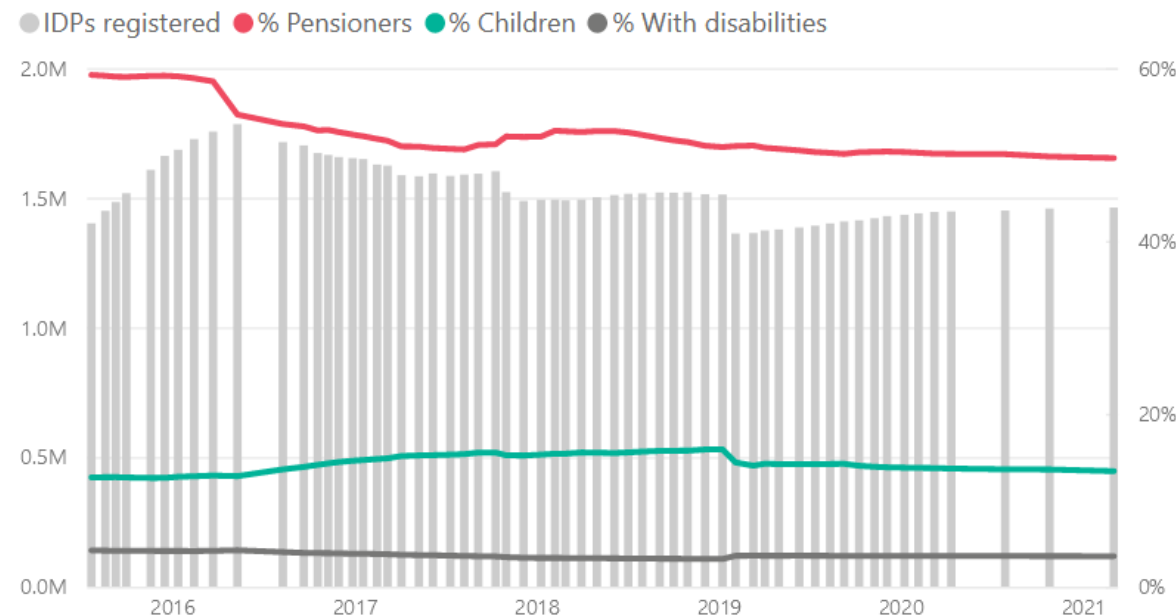
## Distribution of IDPs by Oblast



## IDP Categories



## Categories (lines - right axis in %): Monthly trend



This chart reflects the distribution of IDP categories to the total numbers of IDPs. The strata chosen reflect data collected by the MoSP

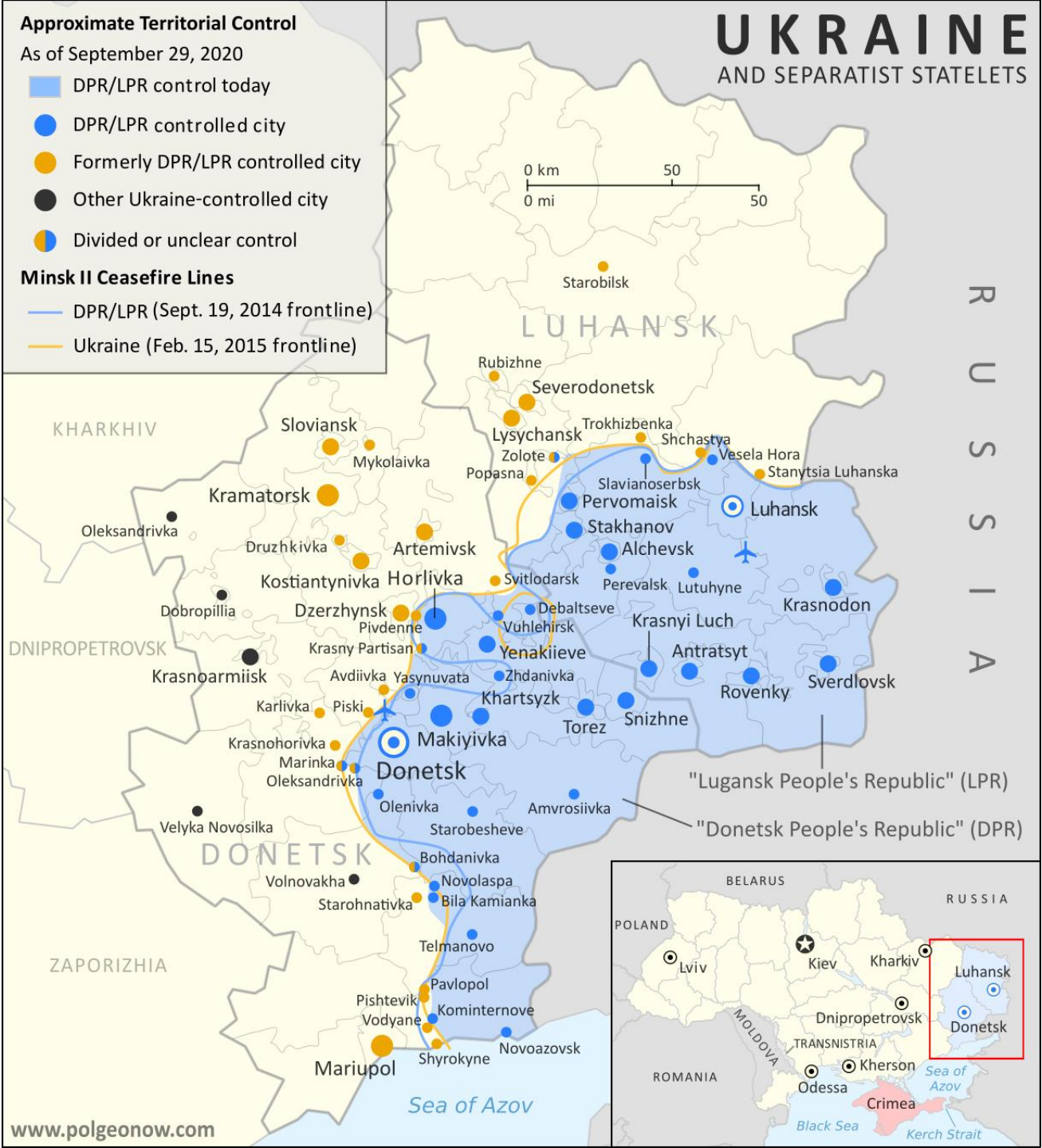
# UKRAINE AND SEPARATIST STATELETS

**Approximate Territorial Control**  
As of September 29, 2020

- DPR/LPR control today
- DPR/LPR controlled city
- Formerly DPR/LPR controlled city
- Other Ukraine-controlled city
- Divided or unclear control

**Minsk II Ceasefire Lines**

- DPR/LPR (Sept. 19, 2014 frontline)
- Ukraine (Feb. 15, 2015 frontline)



# R Scripting: Population Data Process: Read in Data and Count Spaces

```
Sys.setlocale(category = "LC_CTYPE", "Ukrainian")
names_pop20a <- read_xlsx("zb_chuselnist 2019.xlsx", sheet = 12,
                        range = cell_limits(c(7, 1), c(NA, 4)),
                        trim_ws = FALSE,
                        col_names = c("place", "y2018", "y2019", "y2020"),
                        col_types = c("text", "numeric", "numeric", "numeric")) %>%
  filter(grepl("_|^\\d", place) == FALSE & !is.na(y2018) & !is.na(place)) %>%
  as.data.frame()
i = 13
for (i in 13:81){
  names_pop20b <- read_xlsx("zb_chuselnist 2019.xlsx", sheet = i,
                          range = cell_limits(c(4, 1), c(NA, 4)),
                          trim_ws = FALSE,
                          col_names = c("place", "y2018", "y2019", "y2020"),
                          col_types = c("text", "numeric", "numeric", "numeric")) %>%
    filter(grepl("_|^\\d", place) == FALSE & !is.na(y2018) & !is.na(place)) %>%
    as.data.frame()
  names_pop20a <- rbind(names_pop20a, names_pop20b)
  i = i + 1
}
names_pop20 <- names_pop20a
names_pop20$spaces <- nchar(gsub("\\S.*$", "", names_pop20$place))
summary(as.factor(names_pop20$spaces))
# 0  1  2  3  4  5  6  7  8  9
# 24 53 537  4 886  1  3 24 998  6
names_pop20 <- names_pop20[grepl("населення", names_pop20$place) == FALSE,]
summary(as.factor(names_pop20$spaces))
# 0  1  2  3  6  7  8  9
# 24 11 537  1  3 24 998  6
```

# R Scripting: Population Data Process: Identifying Region Names

```
names_pop20$place[nrow(names_pop20)] <- "м. Київ"
names_pop20$place <- gsub("с", "c", names_pop20$place)
names_pop20$admin1 <- ifelse(names_pop20$spaces == 0 &
                             grepl(
                               "Україна|область|Республіка|Севастополь",
                               names_pop20$place) == TRUE,
                             str_trim(names_pop20$place),
                             NA) %>% na.locf()
names_pop20$admin1[nrow(names_pop20)] <- names_pop20$place[nrow(names_pop20)]
names_pop20$admin2 <- ifelse(names_pop20$spaces > 0 & names_pop20$spaces < 5,
                             str_trim(names_pop20$place),
                             ifelse(row.names(names_pop20) == 1,
                                     names_pop20$place,
                                     NA) %>% na.locf())
names_pop20$admin2[nrow(names_pop20)] <- names_pop20$place[nrow(names_pop20)]
names_pop20$admin4 <- ifelse(grepl("м\\.|снт", names_pop20$place) == TRUE,
                             str_trim(names_pop20$place),
                             NA)
names_pop20$admin4 <- str_replace(names_pop20$admin4, "\\.[[:space:]]?", ". ")
names_pop20$admin4[nrow(names_pop20)] <- names_pop20$place[nrow(names_pop20)]
```

# R Scripting: Population Data Process: New and Former Names

```
names_pop20$admin1 <- ifelse(names_pop20$admin4 == "м. Київ",
                             "Київська міська рада",
                             names_pop20$admin1)
names_pop20$admin2 <- ifelse(names_pop20$admin4 == "м. Київ",
                             "Київська міськрада",
                             names_pop20$admin2)

names_pop20$place[grepl("\\([^м]", names_pop20$place) == TRUE]
names_pop20$admin1_old <- gsub("\\([^міськрада].*\\)[[:space:]]", "", names_pop20$admin1)
names_pop20$admin1_new <- gsub("[[:space:]]\\([^міськрада].*$", "", names_pop20$admin1)
names_pop20$admin2_old <- gsub("^.*.\\([^міськрада]\\)[[:space:]]", "", names_pop20$admin2)
names_pop20$admin2_old <- gsub("\\)[[:digit:]].*$", "", names_pop20$admin2_old)
names_pop20$admin2_new <- trimws(gsub("\\(колишн(є|ій|я).*$", "", names_pop20$admin2))

names_pop20$admin4_old <- gsub("^.*.\\(?!міськрада", "", names_pop20$admin4)
names_pop20$admin4_old <- gsub("\\)[[:digit:]].*$", "", names_pop20$admin4_old)
names_pop20$admin4_new <- trimws(gsub("[[:space:]]\\([^міськрада].*$", "", names_pop20$admin4))

names_pop20$admin1 <- names_pop20$admin1_old
names_pop20$admin2 <- names_pop20$admin2_old
names_pop20$admin4 <- names_pop20$admin4_old
```

# R Scripting: Population Data Process: Creating Unique Identifiers

```
names_pop20 <- names_pop20[!is.na(names_pop20$admin4),
                           c("y2018", "y2019", "y2020", "admin1", "admin2", "admin4",
                              "admin1_old", "admin2_old", "admin4_old",
                              "admin1_new", "admin2_new", "admin4_new")]

for (i in 1:nrow(names_pop20)){
  names_pop20$dups19[i] <- nrow(
    names_pop20[
      paste(names_pop20$admin1, names_pop20$admin4) ==
        paste(names_pop20$admin1[i], names_pop20$admin4[i]),])
}

for (i in 1:nrow(names_pop20)){
  names_pop20$dups20[i] <- nrow(
    names_pop20[
      paste(names_pop20$admin1_new, names_pop20$admin4_new) ==
        paste(names_pop20$admin1_new[i], names_pop20$admin4_new[i]),])
}

names_pop20$id19 <- ifelse(
  names_pop20$dups19 == 1,
  paste(names_pop20$admin1, names_pop20$admin4),
  paste(names_pop20$admin1, names_pop20$admin2, names_pop20$admin4)
)

names_pop20$id20 <- ifelse(
  names_pop20$dups20 == 1,
  paste(names_pop20$admin1_new, names_pop20$admin4_new),
  paste(names_pop20$admin1_new, names_pop20$admin2_new, names_pop20$admin4_new)
)
```



# R Scripting: Population Data Process: Manual Adjustments

```
names_pop20$id19 <- ifelse(
  names_pop20$id19 == "Дніпропетровська область смт Миколаївка",
  "Дніпропетровська область Петриківський район смт Миколаївка",
  names_pop20$id19
)
names_pop20$id20 <- ifelse(
  names_pop20$id20 == "Дніпропетровська область смт Миколаївка",
  "Дніпропетровська область Петриківський район смт Миколаївка",
  names_pop20$id20
)
names_pop20$id19 <- ifelse(
  grepl("Київська область м. Переяслав", names_pop20$id19) == TRUE,
  "Київська область м. Переяслав-Хмельницький",
  names_pop20$id19
)
names_pop20$id20 <- ifelse(
  grepl("Київська область м. Переяслав", names_pop20$id20) == TRUE,
  "Київська область м. Переяслав-Хмельницький",
  names_pop20$id20
)
```



# R Scripting: Population Data Process: Finalizing Unique Identifiers

```
names_pop$id <- gsub("[[:space:]]{2}", " ", names_pop$id)
names_pop$id <- ifelse(
  names_pop$id == "Автономна Республіка Крим смт Голуба затока",
  "Автономна Республіка Крим смт Голуба Затока",
  ifelse(
    names_pop$id == "Автономна Республіка Крим смт Симеїз",
    "Автономна Республіка Крим смт Сімеїз",
    ifelse(
      names_pop$id == "Львівська область смт Журавне",
      "Львівська область смт Журавно",
      ifelse(
        names_pop$id == "Полтавська область м. Решетилівка",
        "Полтавська область смт Решетилівка",
        names_pop$id
      )
    )
  )
)
names_pop$id <- gsub("Єнакієве \\(міськрада\\)", "Єнакіївська міськрада", names_pop$id)
names_pop$id <- gsub("Краматорськ \\(міськрада\\)", "Краматорська міськрада", names_pop$id)
names_pop$id <- gsub("Сніжне \\(міськрада\\)", "Сніжнянська міськрада", names_pop$id)
names_pop$id <- gsub("Харцизьк \\(міськрада\\)", "Харцизька міськрада", names_pop$id)
names_pop$id <- gsub("Ровеньки \\(міськрада\\)", "Ровеньківська міськрада", names_pop$id)
names_pop$id <- gsub("Севастополь \\(міськрада\\)", "Севастопольська міська рада", names_pop$id)

names_pop$id_pop <- names_pop$id
```



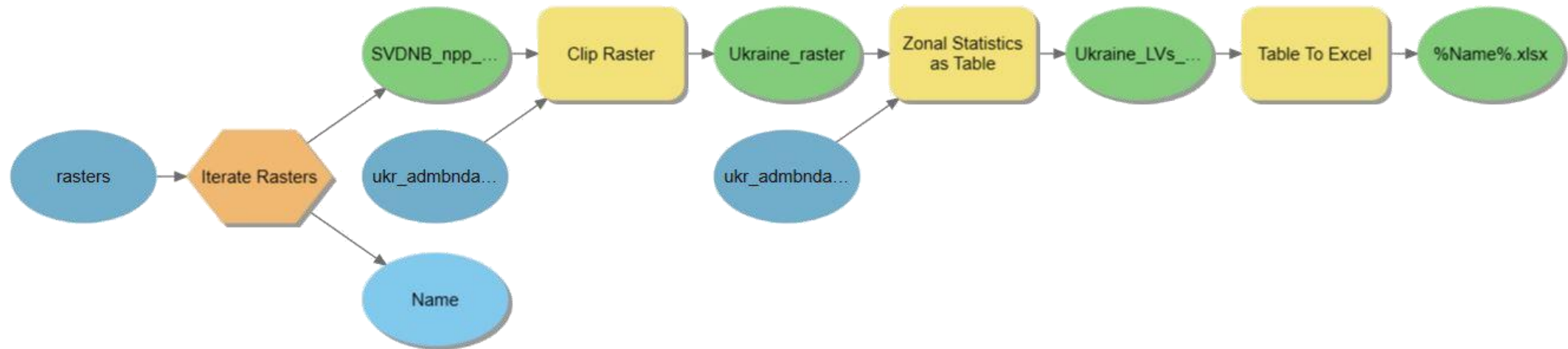
# R Scripting: UN Shapefiles Attribute Data Process: Merging

```
names_ocha$dups <- c()
for (i in 1:nrow(names_ocha)){
  names_ocha$dups[i] <- nrow(names_ocha[
    paste(names_ocha$admin1, names_ocha$admin4) == paste(names_ocha$admin1[i], names_ocha$admin4[i]),
    ])
}
names_ocha$id <- ifelse(
  names_ocha$dups == 1,
  id <- paste(names_ocha$admin1, names_ocha$admin4),
  id <- paste(names_ocha$admin1, names_ocha$admin2, names_ocha$admin4)
)
names_ocha$id_ocha <- names_ocha$id

names_pop_ocha <- merge(names_pop,
  names_ocha,
  by = "id",
  all = TRUE,
  suffixes = c("pop", "ocha"))
View(names_pop_ocha[is.na(names_pop_ocha$id) | is.na(names_pop_ocha$id_ocha) | is.na(names_pop_ocha$id_pop),
  c("id_pop", "id_ocha")])
```

# Nighttime Lights Raster Data Process: City Method

- Untar EOG lights rasters
- Run model:



# Python Scripting: Clipping Nighttime Lights Rasters

```
import arcpy
arcpy.env.workspace = "e:/rasters"
arcpy.env.overwriteOutput = True
rasters = arcpy.ListRasters(
    "*avg_rade9h*",
    "TIF"
)
ukr_admbnda_adm0 = "ukr_admbnda_adm_q2_sspe_20171221.gdb/ukr_admbnda_adm0_q2_sspe_20171221"
for raster in rasters:
    rname = "ukr_lights_"+raster[10:16]
    outpath = "finalproject_ukrainelights.gdb/"+rname
    arcpy.management.Clip(
        in_raster=raster,
        out_raster=outpath,
        in_template_dataset=ukr_admbnda_adm0,
        nodata_value="3.4e+38",
        clipping_geometry="ClippingGeometry",
        maintain_clipping_extent="NO_MAINTAIN_EXTENT")
```

# Python Scripting: Joining Population Data to Boundary Files

```
names_pop_ocha = arcpy.conversion.TableToTable(  
    in_rows=names_pop_ocha_csv,  
    out_path=FinalProject_UkraineLights_gdb,  
    out_name="names_pop_ocha",  
    where_clause="",  
    field_mapping="id \"id\" true true false 8000 Text 0 0,First  
)  
  
ukr_pop_adm4 = arcpy.management.AddJoin(  
    in_layer_or_view=ukr_admbnda_adm4,  
    in_field="admin4Pcode",  
    join_table=names_pop_ocha,  
    join_field="admin4Pcode",  
    join_type="KEEP_ALL"  
) [0]
```



# Python Scripting: Creating Population Rasters

```
for y in range(2013, 2021):
    fname = "y" + str(y)
    rname = "pop" + str(y)
    arcpy.conversion.PolygonToRaster(
        in_features="ukr_pop_adm4",
        value_field=fname,
        out_rasterdataset=rname,
        cell_assignment="CELL_CENTER",
        priority_field="NONE",
        cellsize="ukr_lights_201301",
        build_rat="BUILD"
    )
```

# Python Scripting: Calculating Year-over-Year Differences

```
pop2014_2013 = Raster("pop2014") - Raster("pop2013")
lights2014_2013 = Raster("ukr_lights_201401") - Raster("ukr_lights_201301")
for y in range(2015, 2021):
    rname_in = "pop"+str(y)
    rname_out = "pop"+str(y)+"_2014"
    outraster = Raster(rname_in) - Raster("pop2014")
    outraster.save(rname_out)
    print(rname_out)
    rname_in = "ukr_lights_"+str(y)+"01"
    rname_out = "lights"+str(y)+"_2014"
    outraster = Raster(rname_in) - Raster("ukr_lights_201401")
    outraster.save(rname_out)
    print(rname_out)
print("Executed MapAlgebra.")
```

# Python Scripting: Creating Place Area Rasters

```
arcpy.conversion.PolygonToRaster(  
    in_features="ukr_pop_adm4",  
    value_field="Shape_Area",  
    out_rasterdataset="admin4_Area",  
    cell_assignment="CELL_CENTER",  
    priority_field="NONE",  
    cellsize="ukr_lights_201301",  
    build_rat="BUILD"  
)
```

# Python Scripting: Creating Place Identifier Rasters

```
arcpy.conversion.PolygonToRaster(  
    in_features="ukr_pop_adm4",  
    value_field="admin4Pcode",  
    out_rasterdataset="admin4_Zones",  
    cell_assignment="CELL_CENTER",  
    priority_field="NONE",  
    cellsize="ukr_lights_201301",  
    build_rat="BUILD"  
)
```

# Python Scripting: Creating Zone Containing Populated Places

```
arcpy.management.CalculateField(  
    in_table="ukr_pop_adm4",  
    field="inZone",  
    expression="!y2013!/!y2013!",  
    expression_type="PYTHON3",  
    field_type="DOUBLE"  
)  
arcpy.management.Dissolve(  
    in_features="ukr_pop_adm4",  
    out_feature_class="popZone",  
    dissolve_field="inZone"  
)
```

# Python Scripting: Creating Random Sample Points Within Zone

```
points = arcpy.management.CreateRandomPoints(  
    out_path=FinalProject_UkraineLights_gdb,  
    out_name="points",  
    constraining_feature_class="popZone",  
    number_of_points_or_field=2000,  
    minimum_allowed_distance="0 DecimalDegrees",  
    create_multipoint_output="POINT",  
    multipoint_size=0  
)[0]
```

# Python Scripting: Extracting Selected Rasters to Sample Points

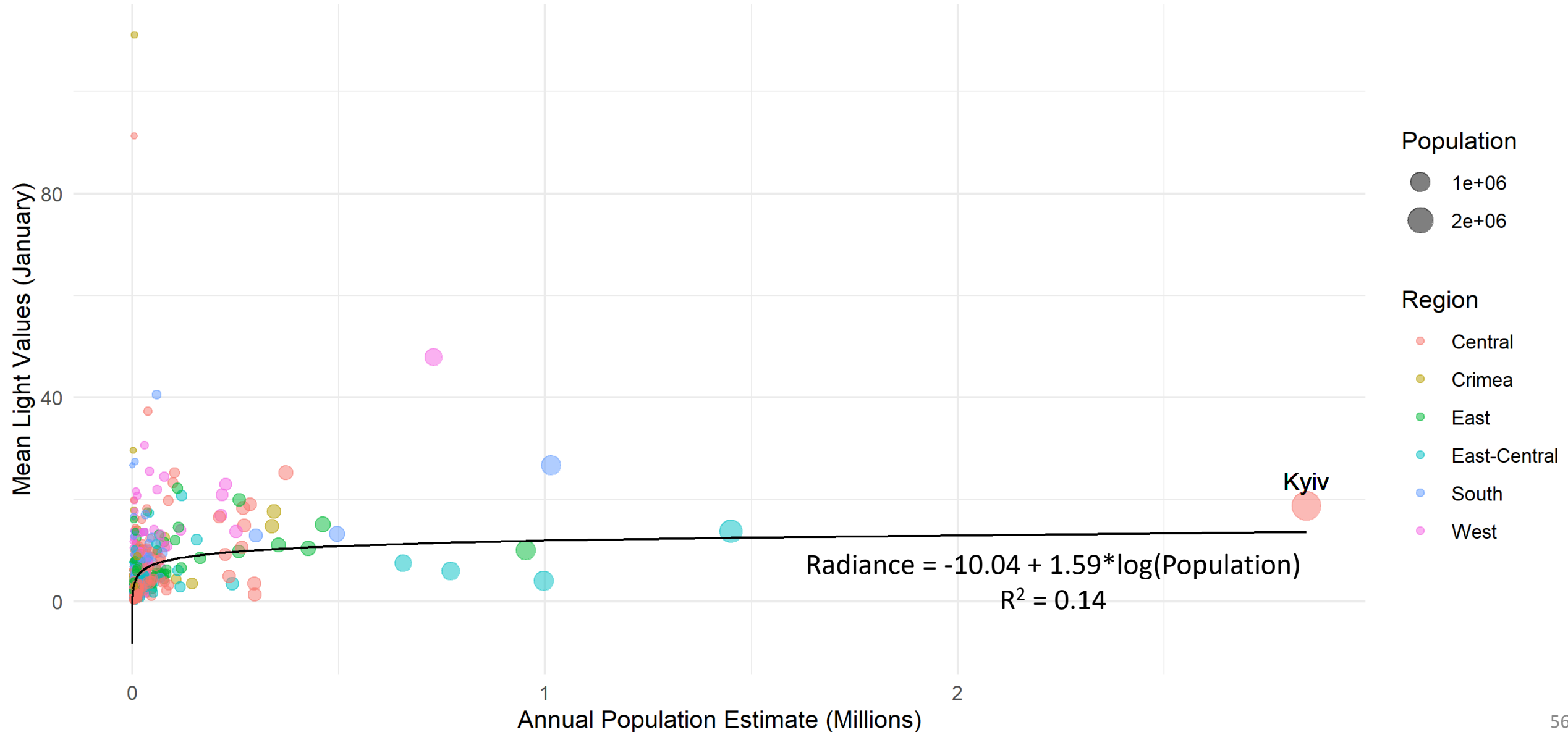
```
rasters1 = arcpy.ListRasters(  
    "ukr_lights*"  
)  
rasters2 = arcpy.ListRasters(  
    "lights20*"  
)  
rasters3 = arcpy.ListRasters(  
    "pop20*"  
)  
rasters4 = arcpy.ListRasters(  
    "admin4*"  
)  
rasters = rasters1+rasters2+rasters3+rasters4  
arcpy.sa.ExtractMultiValuesToPoints(  
    "points",  
    rasters,  
    "NONE"  
)
```

# Python Scripting: Joining with Sample Points and Exporting

```
arcpy.analysis.SpatialJoin(  
    target_features="points",  
    join_features="ukr_pop_adm4",  
    out_feature_class="points_adm4",  
    join_operation="JOIN_ONE_TO_MANY",  
    join_type="KEEP_COMMON",  
    match_option="WITHIN"  
)  
arcpy.conversion.TableToTable(  
    in_rows="points_adm4",  
    out_path=FinalProject_UkraineLights,  
    out_name="points.csv",  
)
```

# Linear Model: log(Population) & Mean Radiance

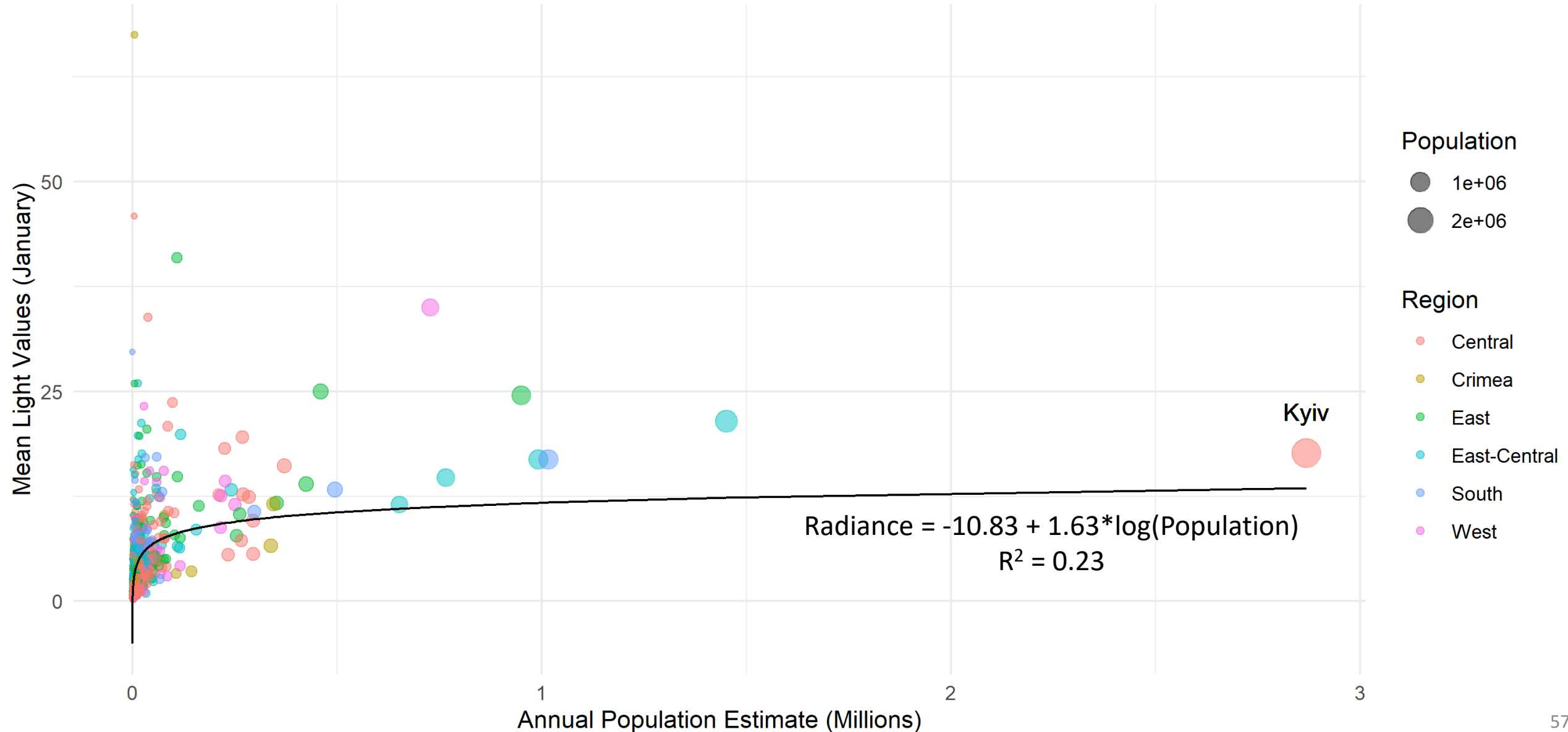
Nighttime Lights vs. Population (2013)





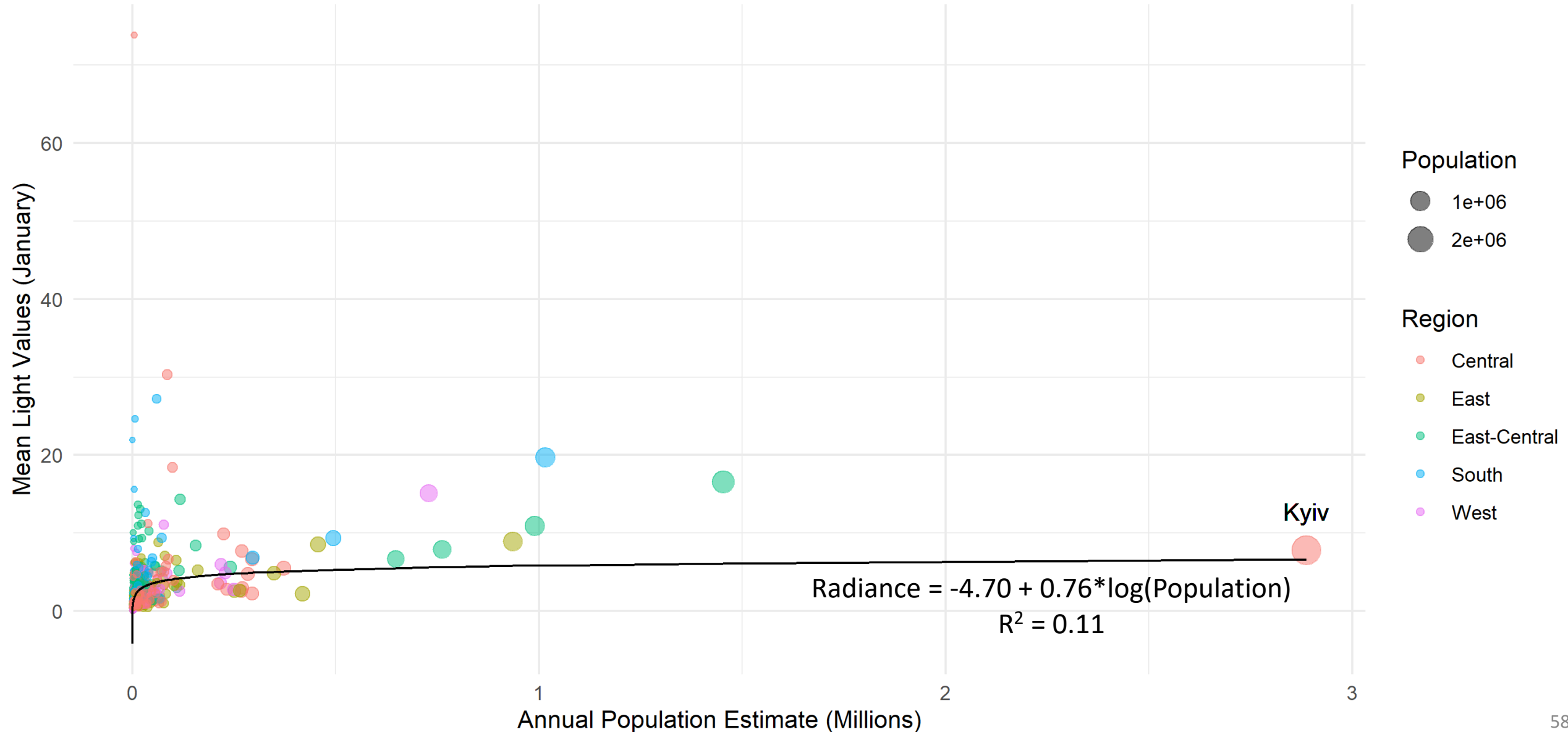
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2014)



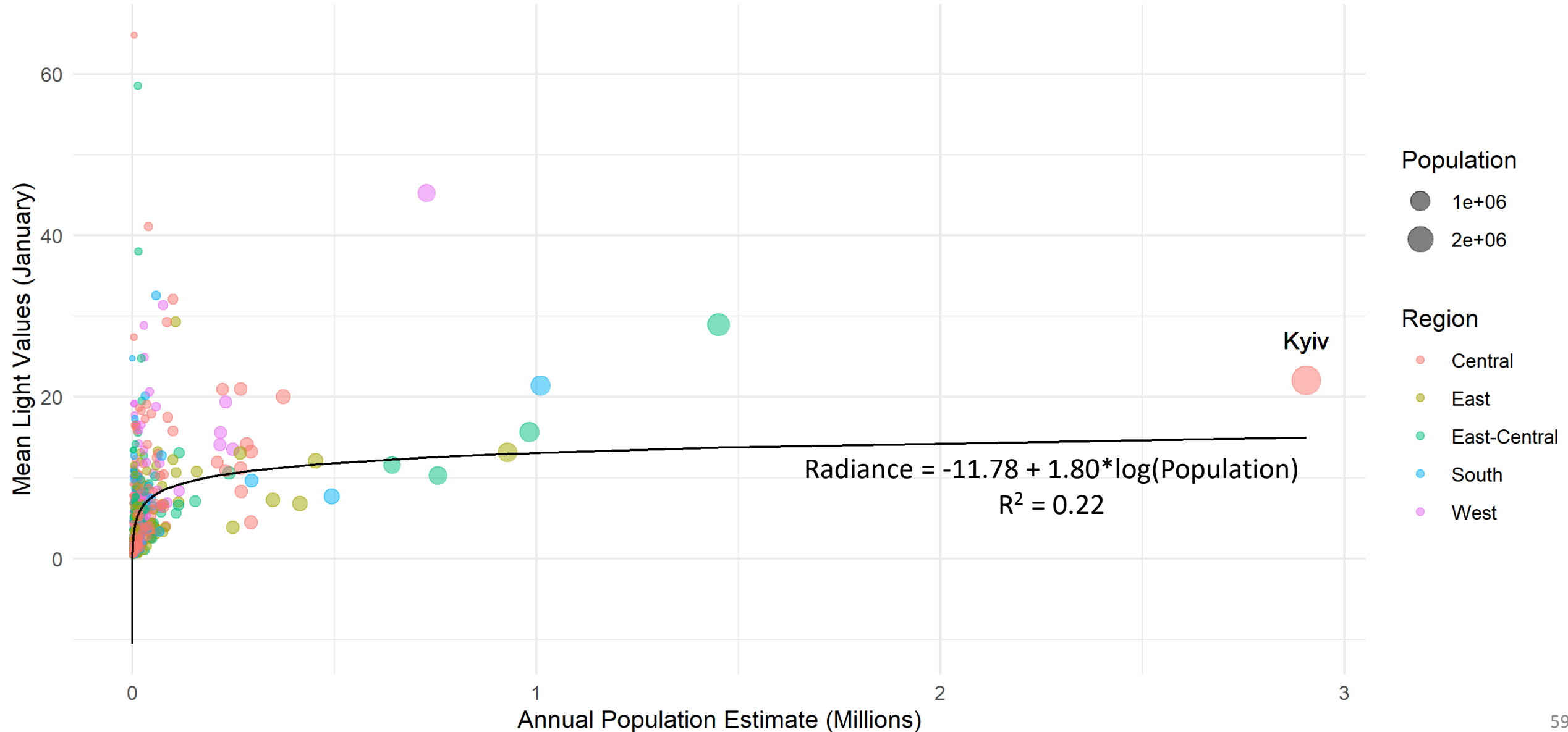
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2015)



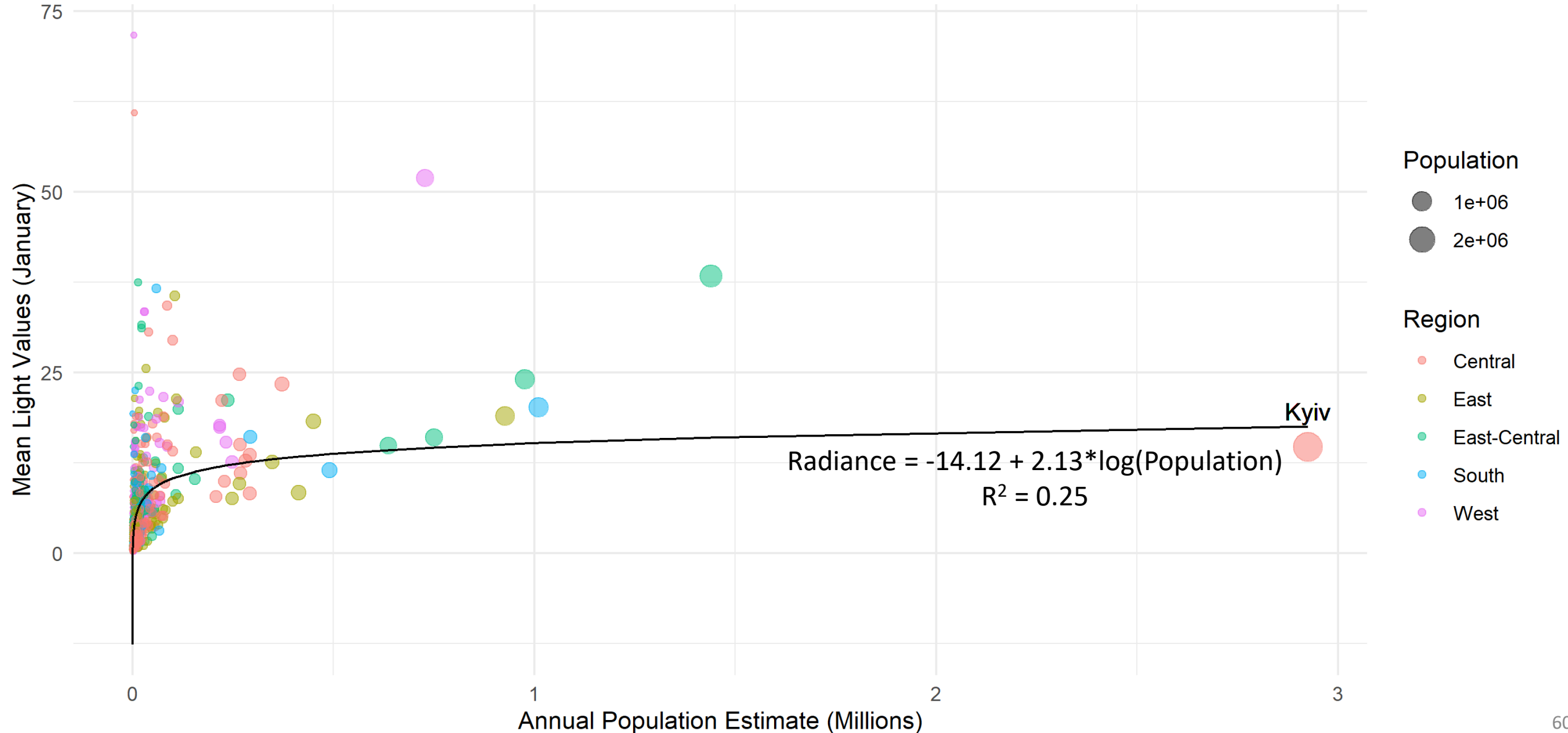
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2016)



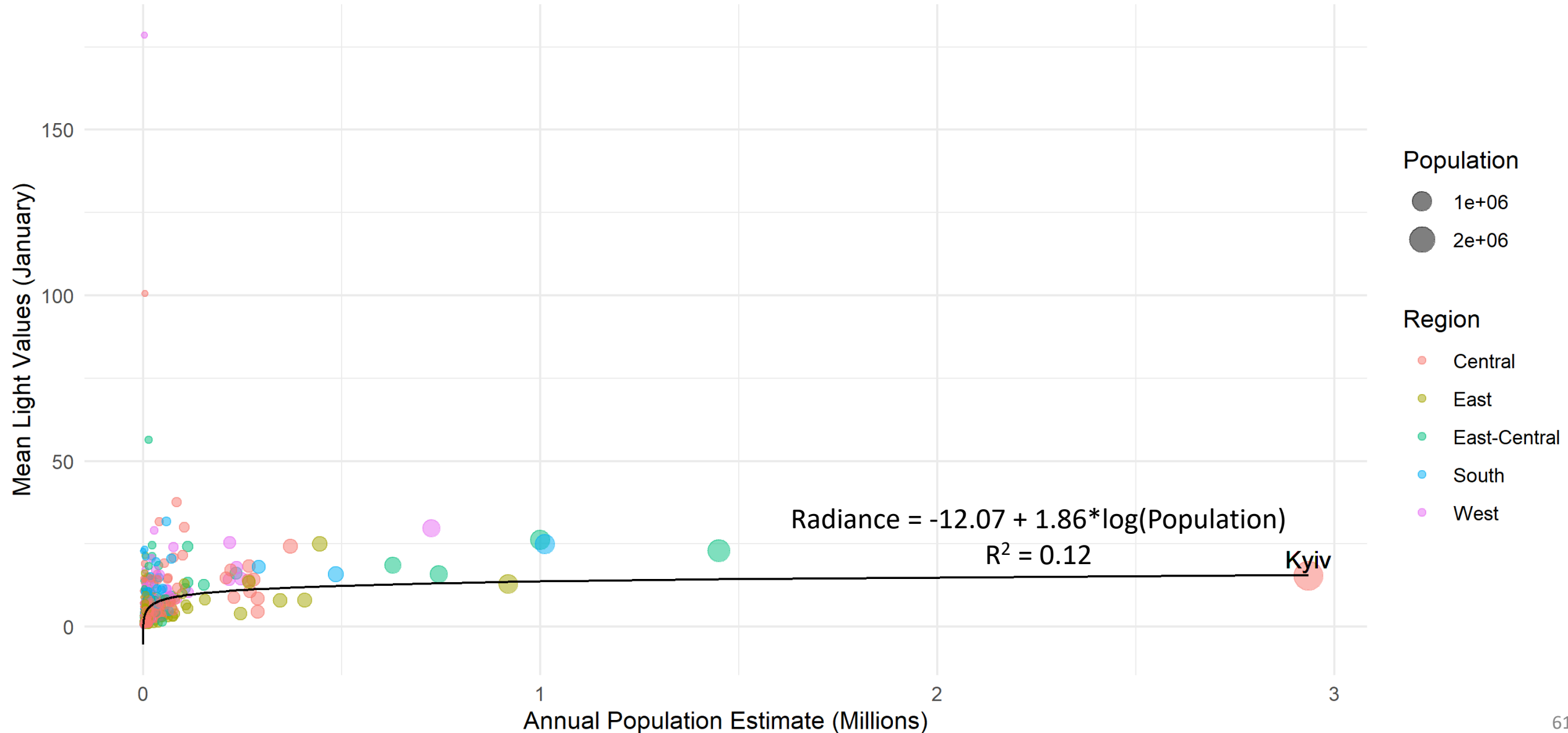
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2017)



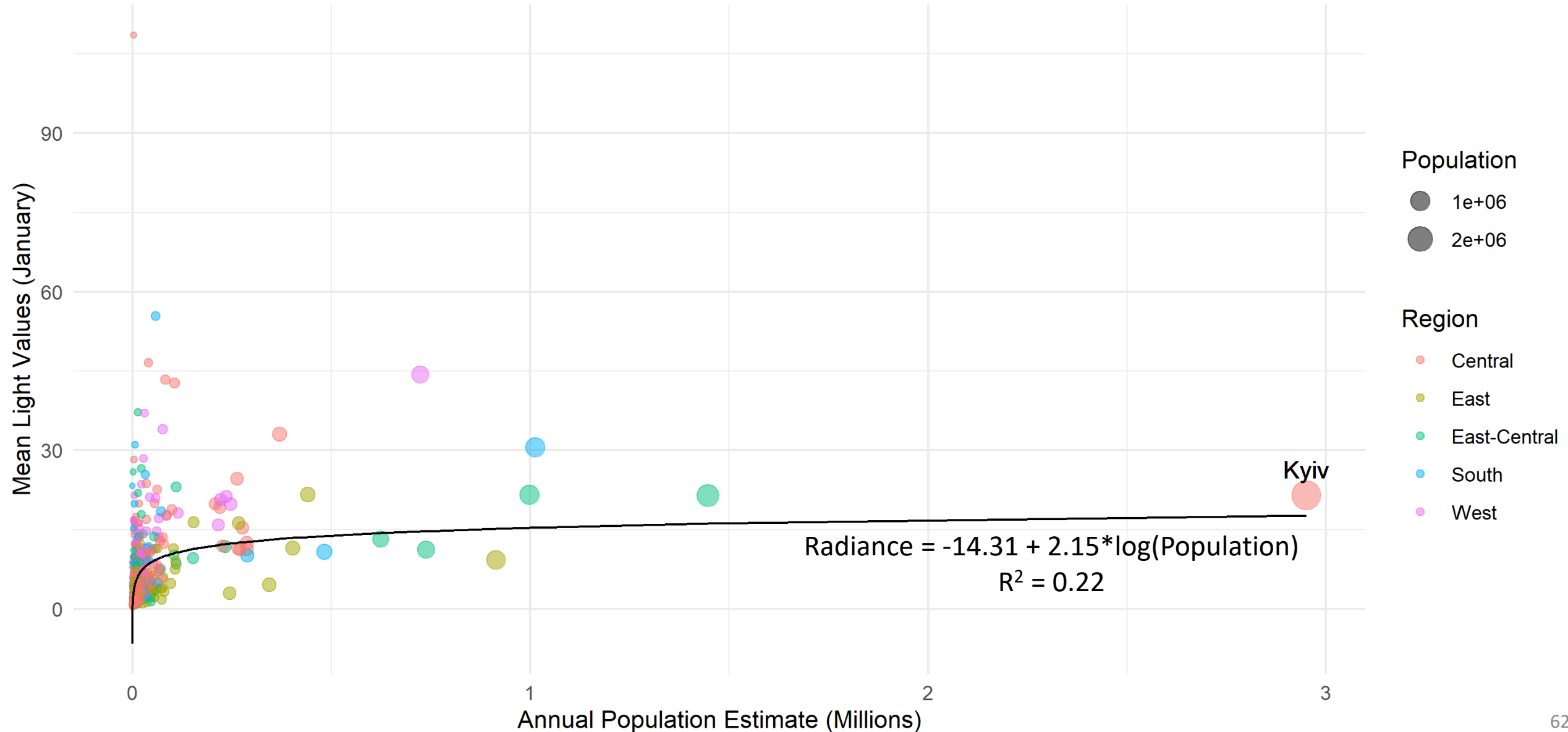
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2018)



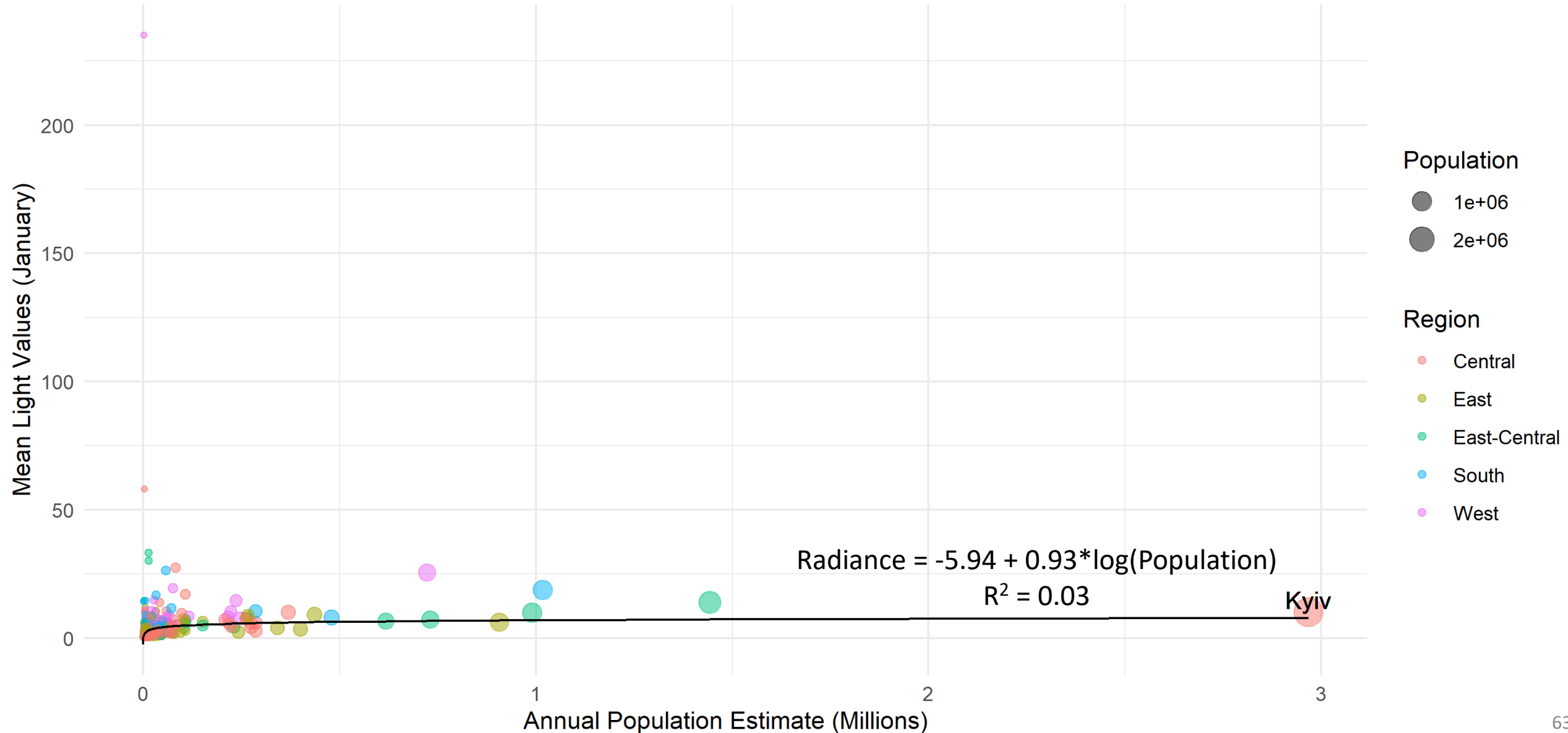
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2019)



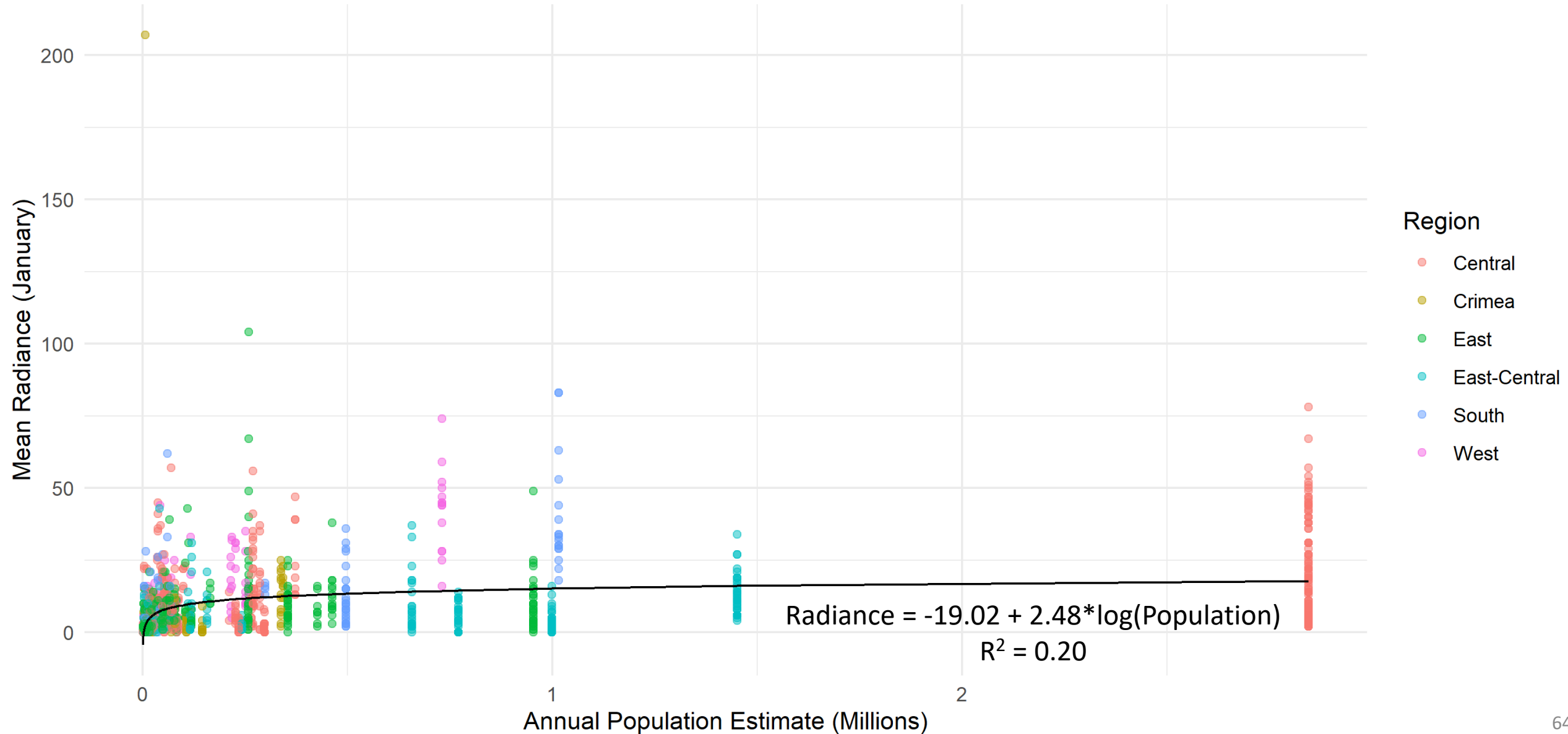
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2020)



# Linear Model: log(Population) & Mean Radiance

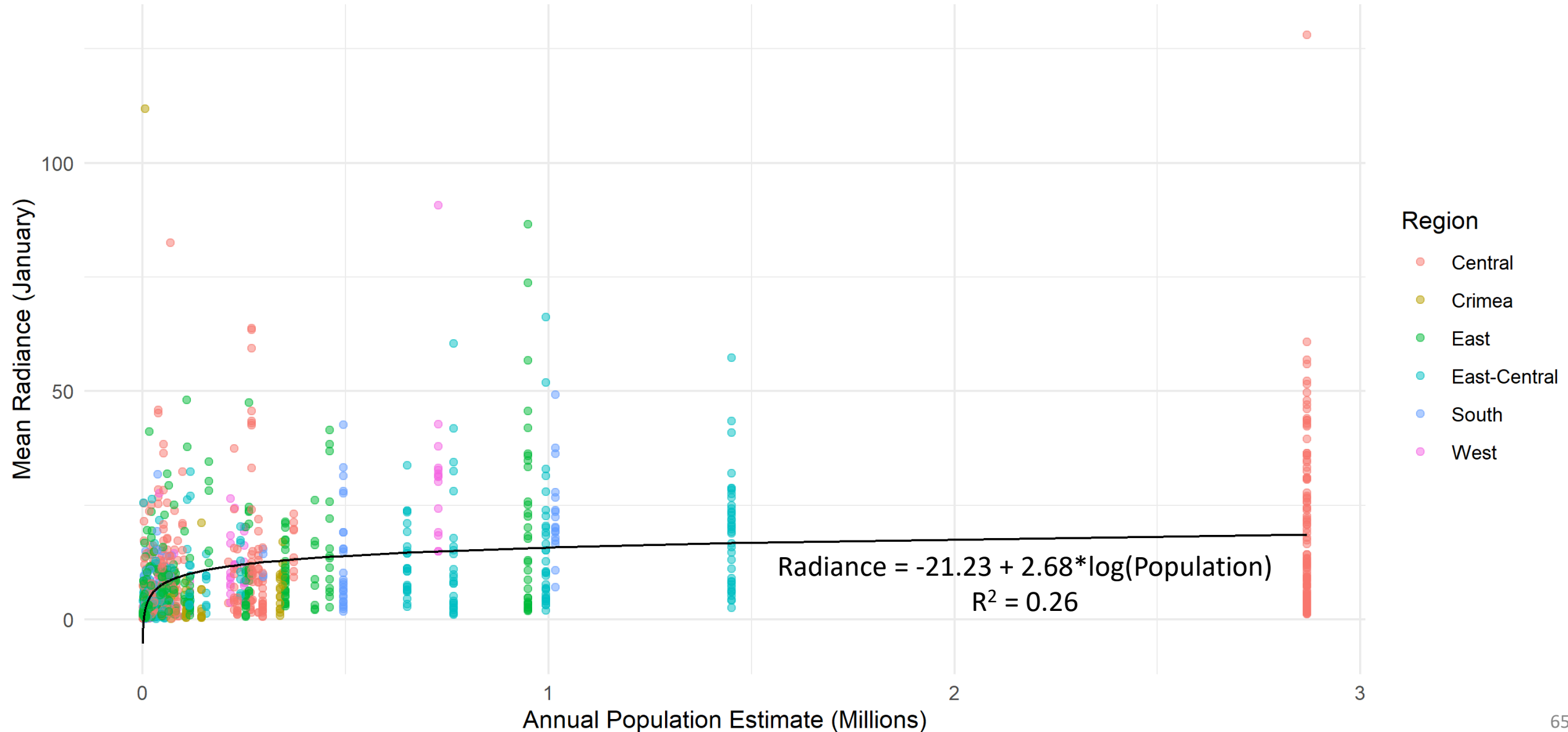
Nighttime Lights vs. Population (2013)





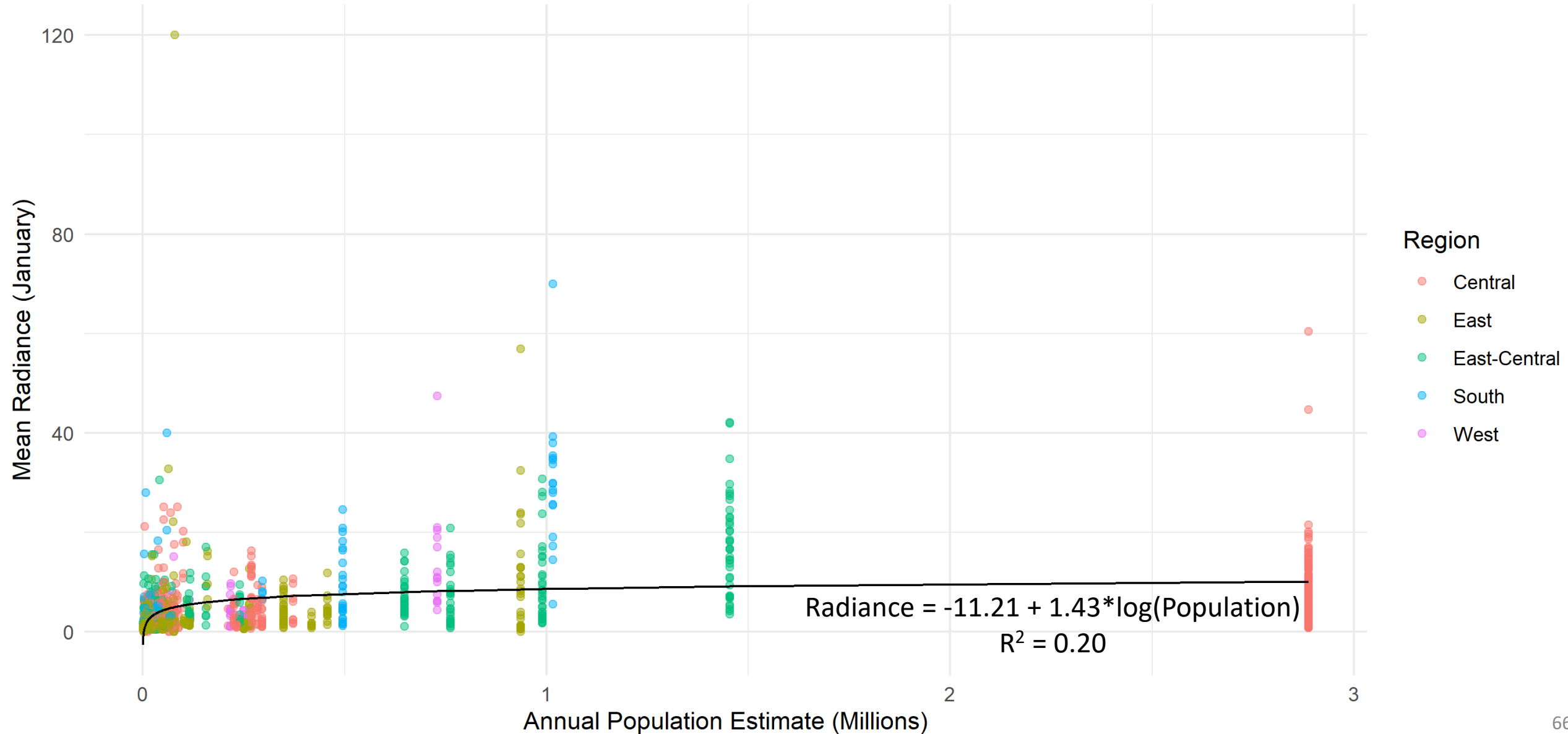
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2014)



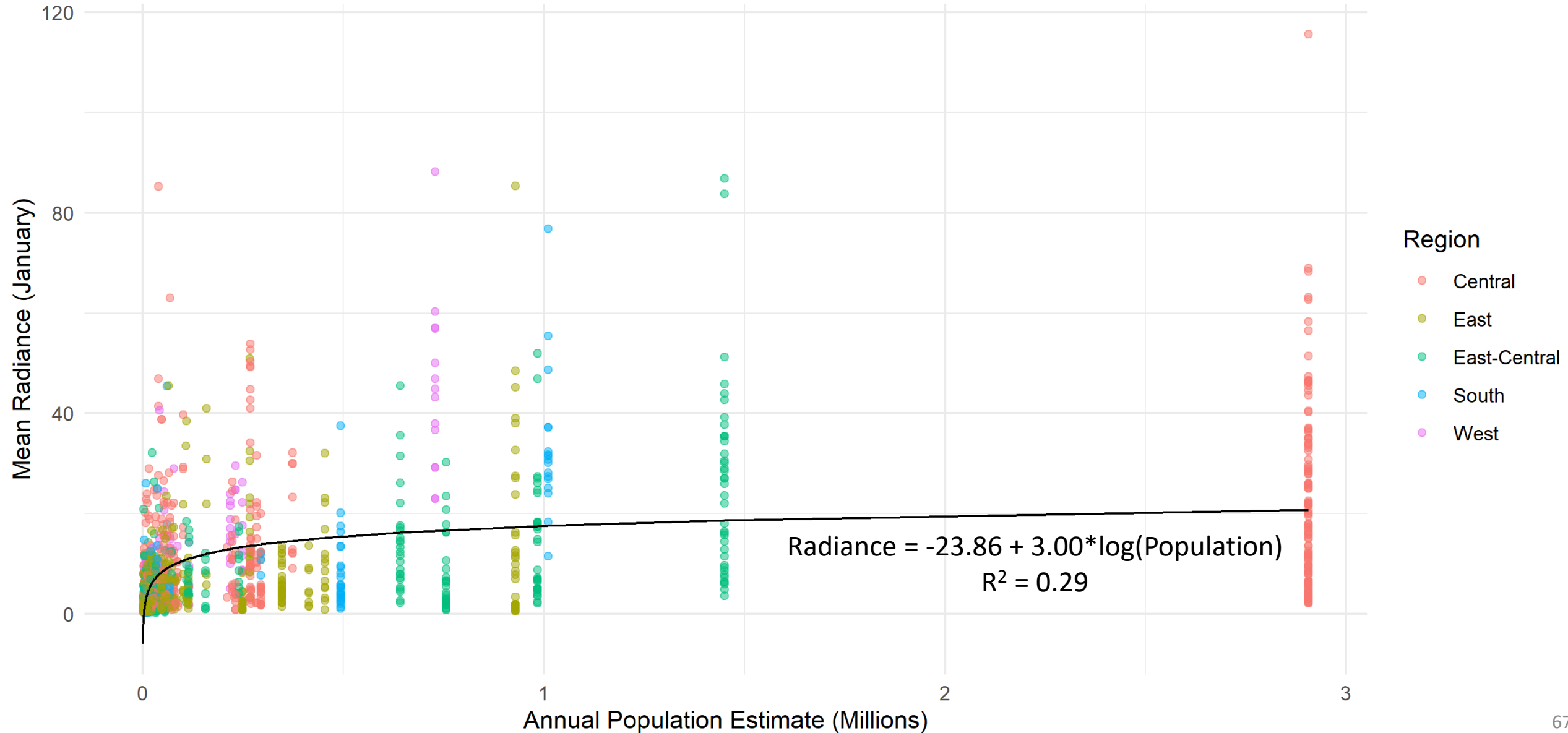
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2015)



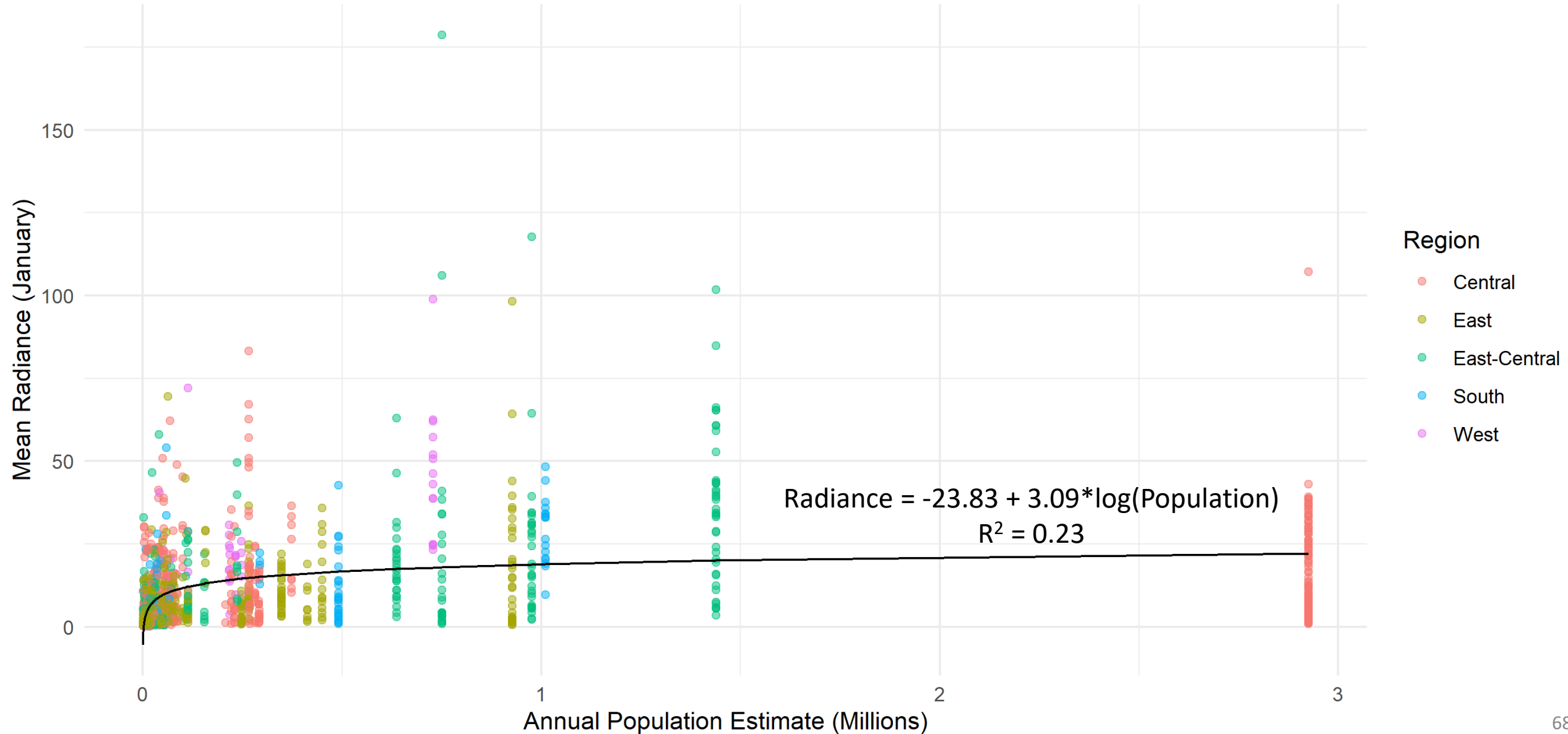
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2016)



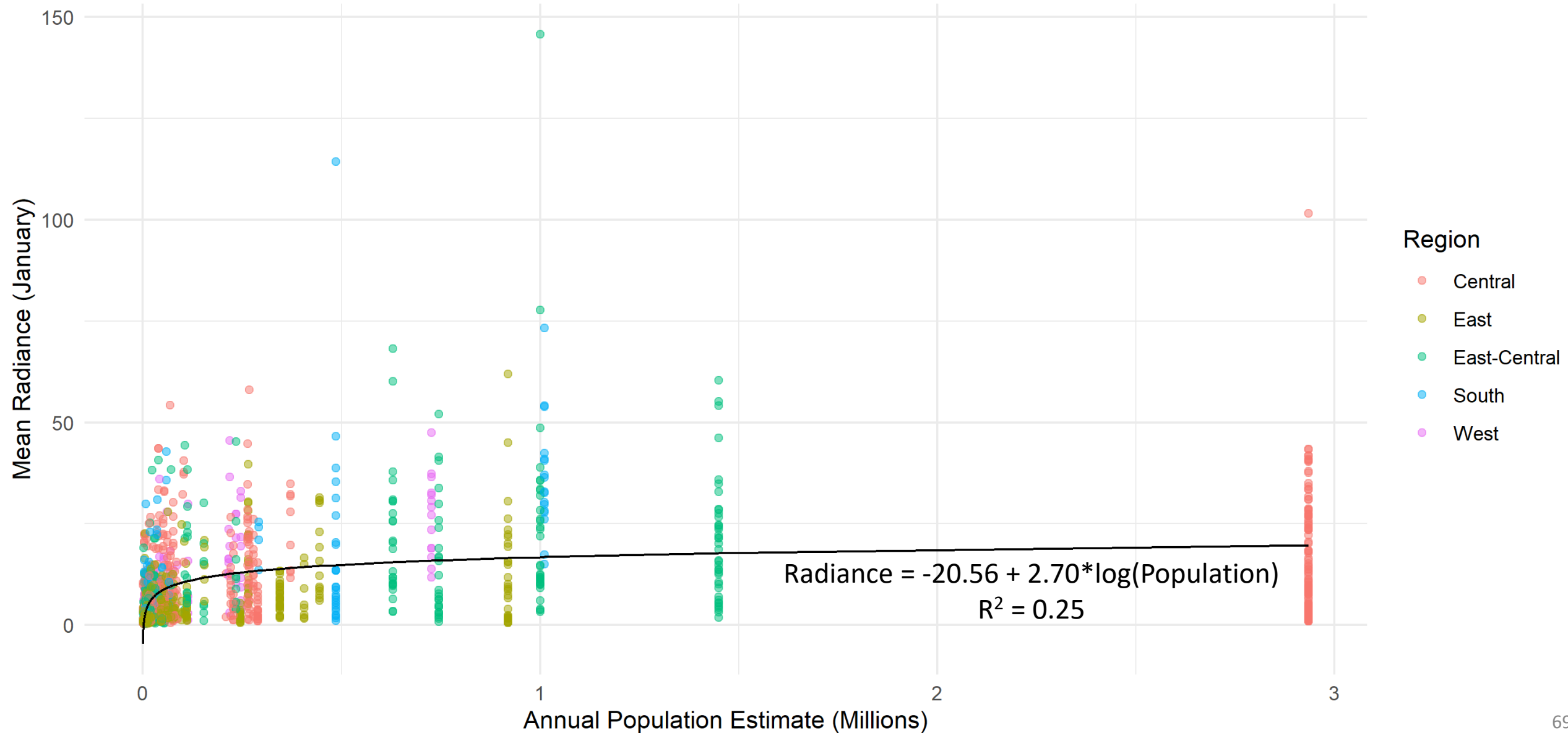
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2017)



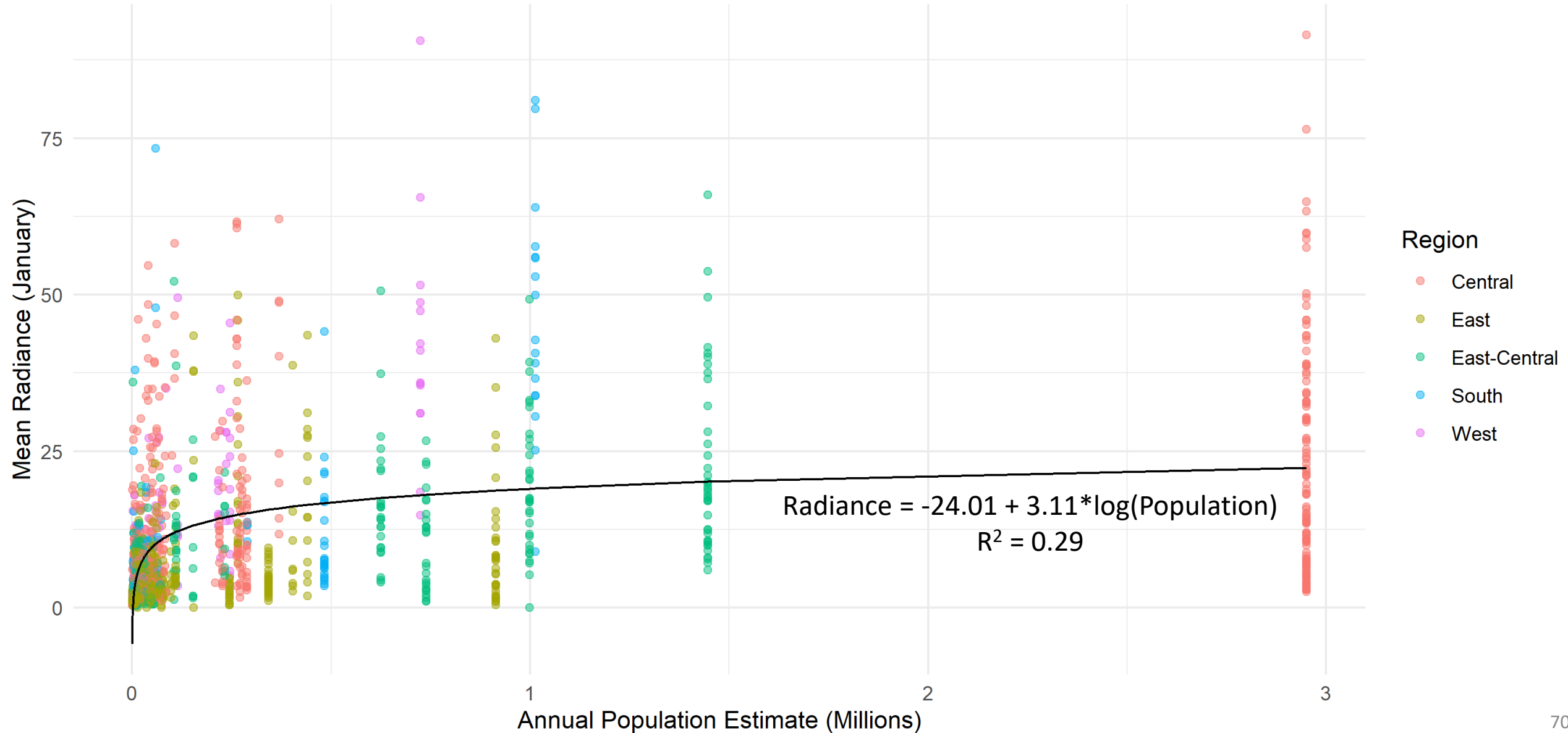
# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2018)



# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2019)



# Linear Model: log(Population) & Mean Radiance

Nighttime Lights vs. Population (2020)

