

Heat Stress Illness Morbidity in the United States

Stephen Lewandowski

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Disclaimer

- The views expressed in this presentation are those of the author and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government

Purpose

- Establish heat as a public health threat
 - Identify different approaches to classifying environmental heat exposure
 - Describe risk factors for heat stress illness outcomes and definitions of outcomes
 - Provide a descriptive background on heat stress illnesses in the United States Army
 - Discuss heat stress illness prevention strategies
 - Outline future research plans
-

Agenda

- ~~Heat as a public health threat~~
 - ~~Heat stress illness outcome definitions~~
 - ~~Heat exposure definitions~~ - NLDAS-2 workflow
 - U.S. Army HSI epidemiology
 - ~~Prevention strategies~~
 - Future research plans
-

Heat is a public health threat

- “Present-day high temperatures (heat) have been conclusively linked to a higher risk of illness and death, particularly among older adults, pregnant women, and children.” (NCA 4, Vol II, 2018)
- Risks vary across regions
 - Local land cover, urban heat islands
 - Topography
 - Resilience of individuals and communities

Associations

Cardiovascular complications
Respiratory complications
Renal failure
Electrolyte imbalance
Negative impacts on fetal health
Preterm birth

More vulnerable

Older, sicker individuals
Lack access to air conditioning
Living in older homes
Socially isolated
Working outdoors

Heat stress illness outcomes (Primary)

- Heat stroke and sunstroke
 - Form of hyperthermia, in which the core body temperature is elevated above (104°F/40 °C), measured immediately following collapse during strenuous activity
 - Considered a medical emergency; can be fatal if not properly treated

Central nervous system dysfunction

Disorientation

Headache

Irrational behavior

Irritability

Emotional instability

Confusion

Altered consciousness

Seizure

Heat stress illness outcomes (Primary)

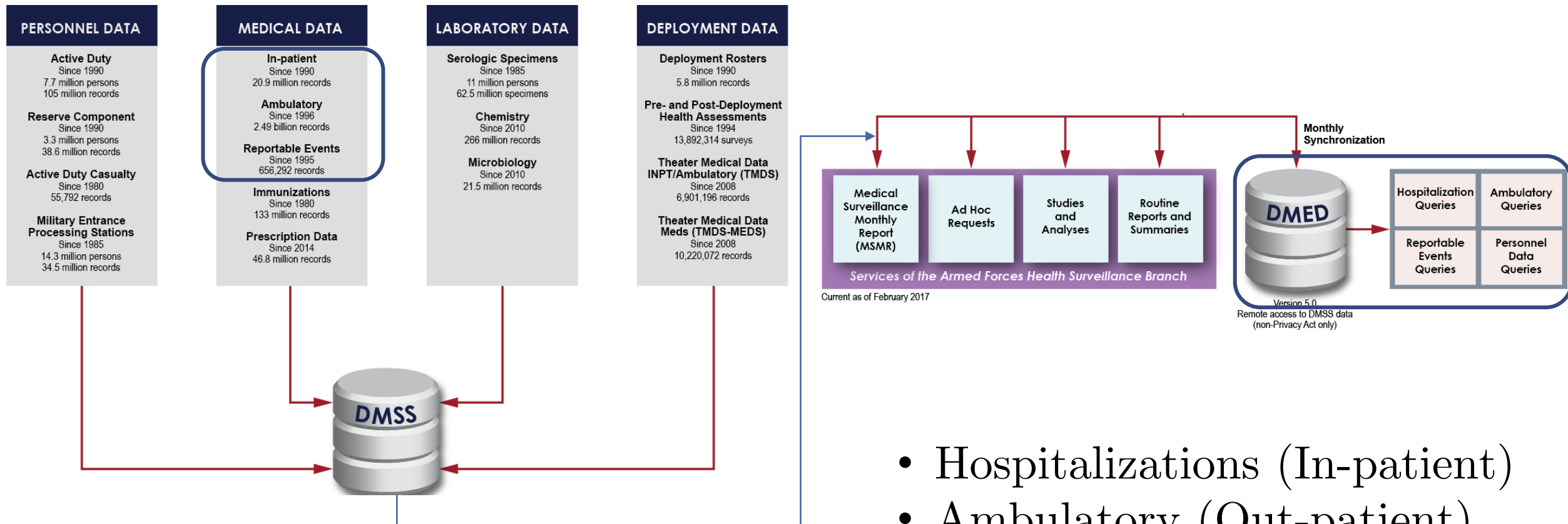
- Heat exhaustion
 - Acute reaction to excessive heat, often accompanied by profuse sweating, dizziness, nausea, headache and fatigue

Types
Anhydrotic (due to water depletion)
Due to salt depletion
Unspecified

Heat stress illness outcomes (Other)

- Heat syncope (fainting)
 - Heat cramps
 - Heat fatigue, transient (temporary state of discomfort and mental or psychological strain)
 - Heat edema (swelling)
 - Other effects of heat and light
 - Effect of heat and light, unspecified
-

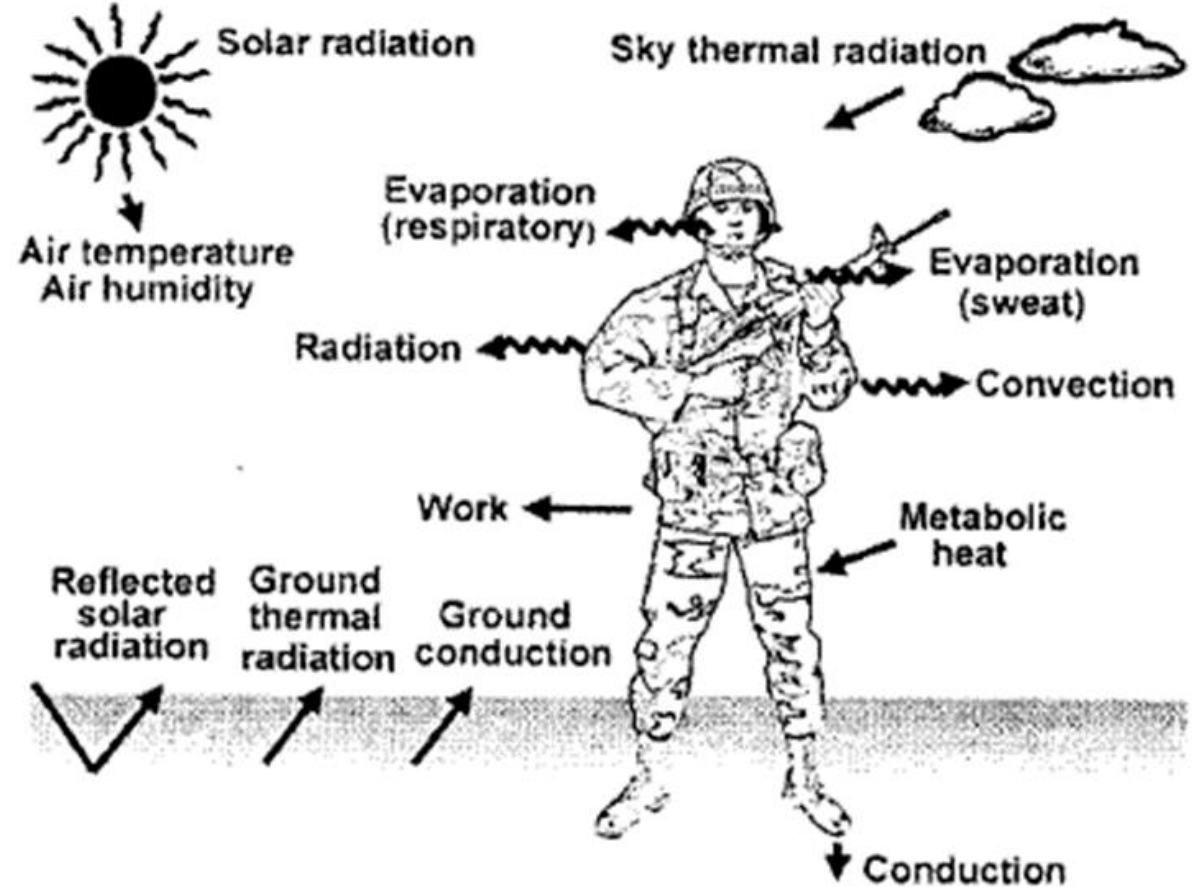
Heat Stress Illness Outcome data



- Hospitalizations (In-patient)
- Ambulatory (Out-patient)

Heat exposure parameters

- Temperature
 - Relative humidity
 - Specific humidity
- Humidity
 - Relative humidity
 - Specific humidity
- Wind Speed
- Solar radiation
 - Sun angle
 - Cloud cover
- Indices: Heat Index, Wet Bulb Globe Temperature



Heat exposure classification approaches

- Scales
 - Absolute
 - Relative
 - Averaging
 - Temporal: Hourly, daily, monthly, annually
 - Metric: Maximum, mean, minimum, sum
 - Events (Heat waves)
 - Temperature metric or index
 - Threshold: percentile (relative) or absolute value
 - Duration (e.g. 1 day, 2+ consecutive days)
-

NLDAS-2 Workflow


Lab group

1. Get file URL list – separate URL for each hour

The screenshot shows the NASA EarthData website interface. The browser address bar displays the URL: `disc.gsfc.nasa.gov/datasets/NLDAS_FORA0125_H_002/summary`. The page title is "NLDAS_FORA0125_H: NLDAS Primary Forcing Data L4 Hourly 0.125 x 0.125 degree V002". On the left, there is a map of North America with a color scale for precipitation. The main text describes the data set as "File A" for Phase 2 of the North American Land Data Assimilation System (NLDAS-2), containing hourly forcing data from 1979 to the present. A sidebar on the right titled "Data Access" contains several buttons: "Online Archive", "Earthdata Search", "Simple Subset Wizard", "Giovanni", "GDS", and "Subset / Get Data". A blue arrow points to the "Subset / Get Data" button.

Estimated size of results

14,910 days, 357,840 links, 560.24 GB


Refine Search 

You are about to retrieve 357,840 file links from the archive. You may **speed up** the request by limiting the scope of your search.

▶ Refine Date Range:

1979-01-01 to 2019-10-27

Reset

Subset Options 

▶ Spatial Subset:

-125, 25, -67, 53

Reset

▼ Variables:

Get all variables

Reset

NOTE: By default, **ALL** variables are sent in the subset request.

- ☐ APCP = Precipitation hourly total (kg/m²)
- ☐ CAPE = 180-0 mb above ground Convective Available Potential Energy (J/kg)
- ☐ CONVfrac = Fraction of total precipitation that is convective (unitless)
- ☐ DLWRF = Longwave radiation flux downwards (surface) (W/m²)
- ☐ DSWRF = Shortwave radiation flux downwards (surface) (W/m²)
- ☐ PEVAP = Potential evaporation hourly total (kg/m²)
- ☐ PRES = Surface pressure (Pa)
- ☐ SPFH = 2-m above ground Specific humidity (kg/kg)
- ☐ TMP = 2-m above ground Temperature (K)
- ☐ UGRD = 10-m above ground Zonal wind speed (m/s)
- ☐ VGRD = 10-m above ground Meridional wind speed (m/s)

▶ Grid:

None

Reset

Output format 

▼ File Format:


☒ NetCDF

☐ GRIB (Default)

Reset

Lab group

Results:

Searching for data... (1%) 

Found 12000 files out of estimated 357816, continuing the search (NLDAS_FORA0125_H_002).

Download links list  (This list is valid for 2 days) | [Instructions for downloading](#)

README Document
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▶ Selected Parameters

Cancel request

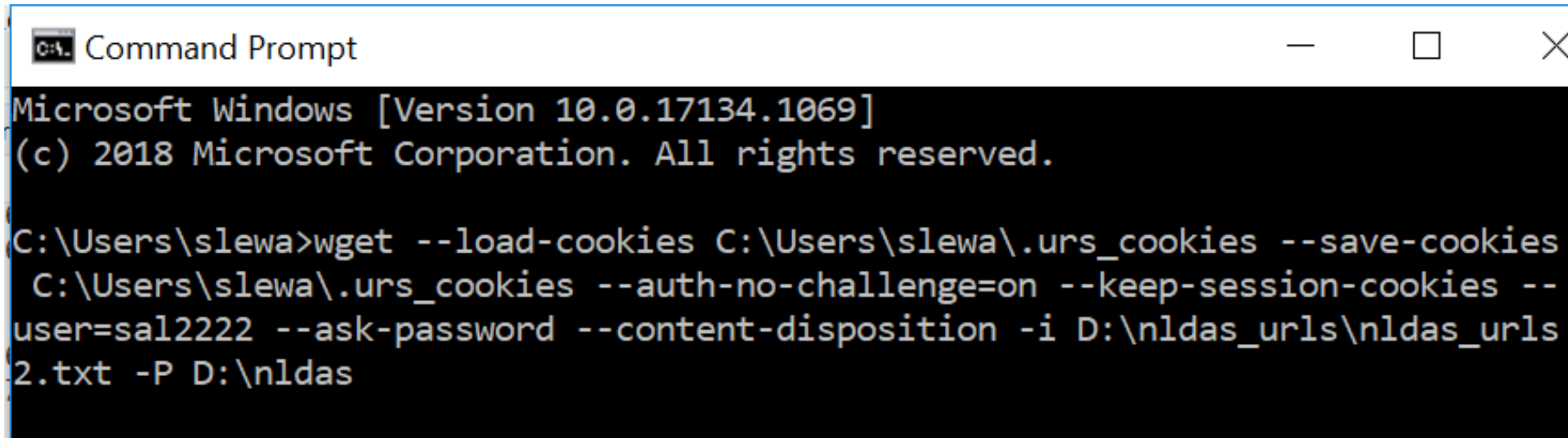
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```


NLDAS-2 Workflow (cont.)

2. Download files from URL list (355,323 files, 2.85 TB)

- Windows PC: install “wget”
- Run from Command prompt



```
Command Prompt
Microsoft Windows [Version 10.0.17134.1069]
(c) 2018 Microsoft Corporation. All rights reserved.

C:\Users\slewa>wget --load-cookies C:\Users\slewa\.urs_cookies --save-cookies
C:\Users\slewa\.urs_cookies --auth-no-challenge=on --keep-session-cookies --
user=sal2222 --ask-password --content-disposition -i D:\nldas_urls\nldas_urls
2.txt -P D:\nldas
```

NLDAS-2 Workflow (cont.)

3. Extract variables from NLDAS-2 netCDF files

- convert .nc4 to raster
- select by raster cell positions
- map over each file and each variable

```
extract_single_file <- function(ncdf_single_file, nldas_var) {  
  hourly_df <-  
    ncdf_single_file %>%  
      file.path(nldas_path, .) %>%  
      raster::brick(varname = nldas_var, quick = TRUE) %>%  
      raster::extract(., cells, df = FALSE) %>%  
      magrittr::set_colnames(nldas_var) %>%  
      as_tibble()  
}
```

```
for (i in seq_along(file_names)) {  
  map2_dfc(.x = file_names[[i]], .y = nldas_variables, .f = extract_single_file) %>%  
  write_rds(., path = paste0("C:/Users/slewa/Documents/data/heat/nldas_raster/",  
                             paste0(  
   file_names[[i]] %>% stringr::str_extract("[1-2][0-9]{7}"),  
   "-",  
   file_names[[i]] %>% stringr::str_extract("\\.[0-2][0-9][0]{2}") %>% str_sub(start = 2L)),  
   ".rds"),  
  compress = "none")  
}
```

464 x 224 grid = 103,936 grid cells

Selected 6 of 11 variables

```
nldas_variables <- c("TMP", "SPFH", "PRES", "UGRD", "VGRD", "DSWRF")
```

NLDAS-2 Workflow (cont.)

4. Compile into list (258,901 elements, 594.6 Mb)

```
$`19900101_0000`
# A tibble: 18 x 6
  TMP      SPFH    PRES    UGRD    VGRD DSWRF
  <dbl>   <dbl>   <dbl>   <dbl>   <dbl> <dbl>
1  290.  0.0116  99900.   3.54    2.63    0
2  277.  0.00411 99214.   4.91   -0.860    0
3  281.  0.00279 85903.  -1.68   -1.52  38.0
4  272.  0.00207 97015.   3.5    -2.20    0
5  287.  0.00209 91889.  -0.570   1.04  68.1
6  290.  0.0112  99640.   2.04    5.05    0
7  278.  0.00179 96697.   3.18   -2.46    0
8  271.  0.00245 83031.   2.97    0.110    0
9  280.  0.00564 100232.   3.38    6.54   8.97
10 286.  0.00815 99994.   3.45    6.88    0
11 275.  0.00434 97379.   0.590   3.86    0
12 281.  0.00520 100950.   3.07   -2.55    0
13 288.  0.0102  99866.   2.45    5.43    0
14 275.  0.00293 97527.   3.28   -0.210    0
15 280.  0.00296 87678.   0.370  -1.84   5.49
16 281.  0.00317 99299.   1.89   -3.08    0
17 274.  0.00406 97167.   2.96    7.12    0
18 290.  0.0115 101103.   2.93    5.42    0
```

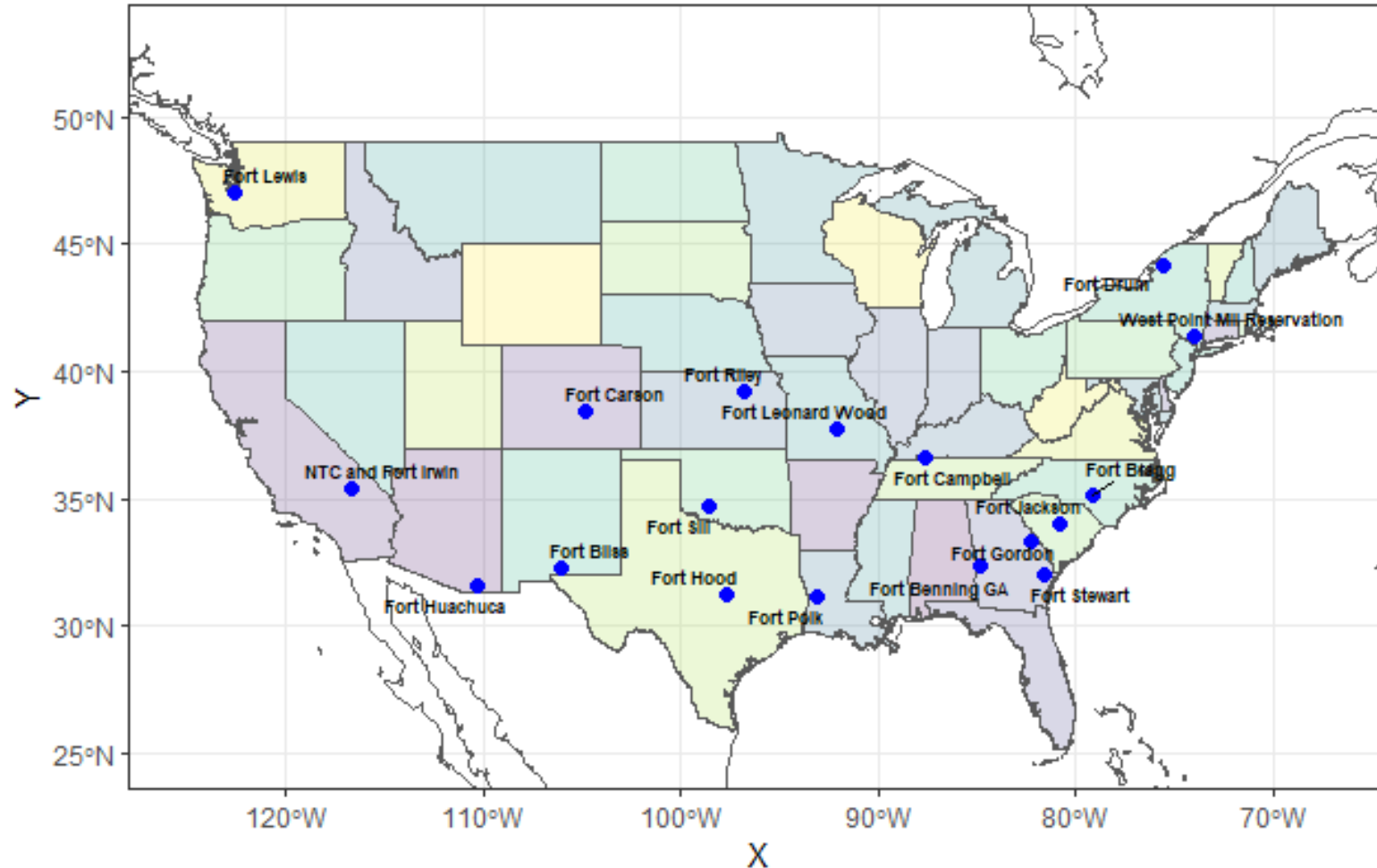
```

sites
[1,] "Fort Benning GA"
[2,] "Fort Campbell"
[3,] "Fort Huachuca"
[4,] "Fort Riley"
[5,] "NTC and Fort Irwin"
[6,] "Fort Gordon"
[7,] "Fort Sill"
[8,] "Fort Carson"
[9,] "Fort Lewis"
[10,] "Fort Bragg"
[11,] "West Point Mil Reservation"
[12,] "Fort Polk"
[13,] "Fort Jackson"
[14,] "Fort Leonard Wood"
[15,] "Fort Bliss"
[16,] "Fort Hood"
[17,] "Fort Drum"
[18,] "Fort Stewart"

cells
"76418"
"61084"
"79462"
"51266"
"65491"
"73191"
"67956"
"53986"
"21828"
"66255"
"43560"
"80992"
"70418"
"56871"
"76712"
"80955"
"33340"
"78300"
```


U.S. Army Background HSI

Selected CONUS US Army Installations



sites

"Fort Benning GA"

"Fort Campbell"

"Fort Huachuca"

"Fort Riley"

"NTC and Fort Irwin"

"Fort Gordon"

"Fort Sill"

"Fort Carson"

"Fort Lewis"

"Fort Bragg"

"West Point Mil Reservation"

"Fort Polk"

"Fort Jackson"

"Fort Leonard Wood"

"Fort Bliss"

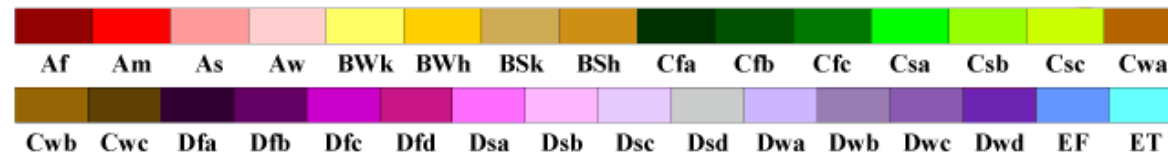
"Fort Hood"

"Fort Drum"

"Fort Stewart"

World Map of Köppen–Geiger Climate Classification

updated with CRU TS 2.1 temperature and VASclimO v1.1 precipitation data 1951 to 2000



Main climates

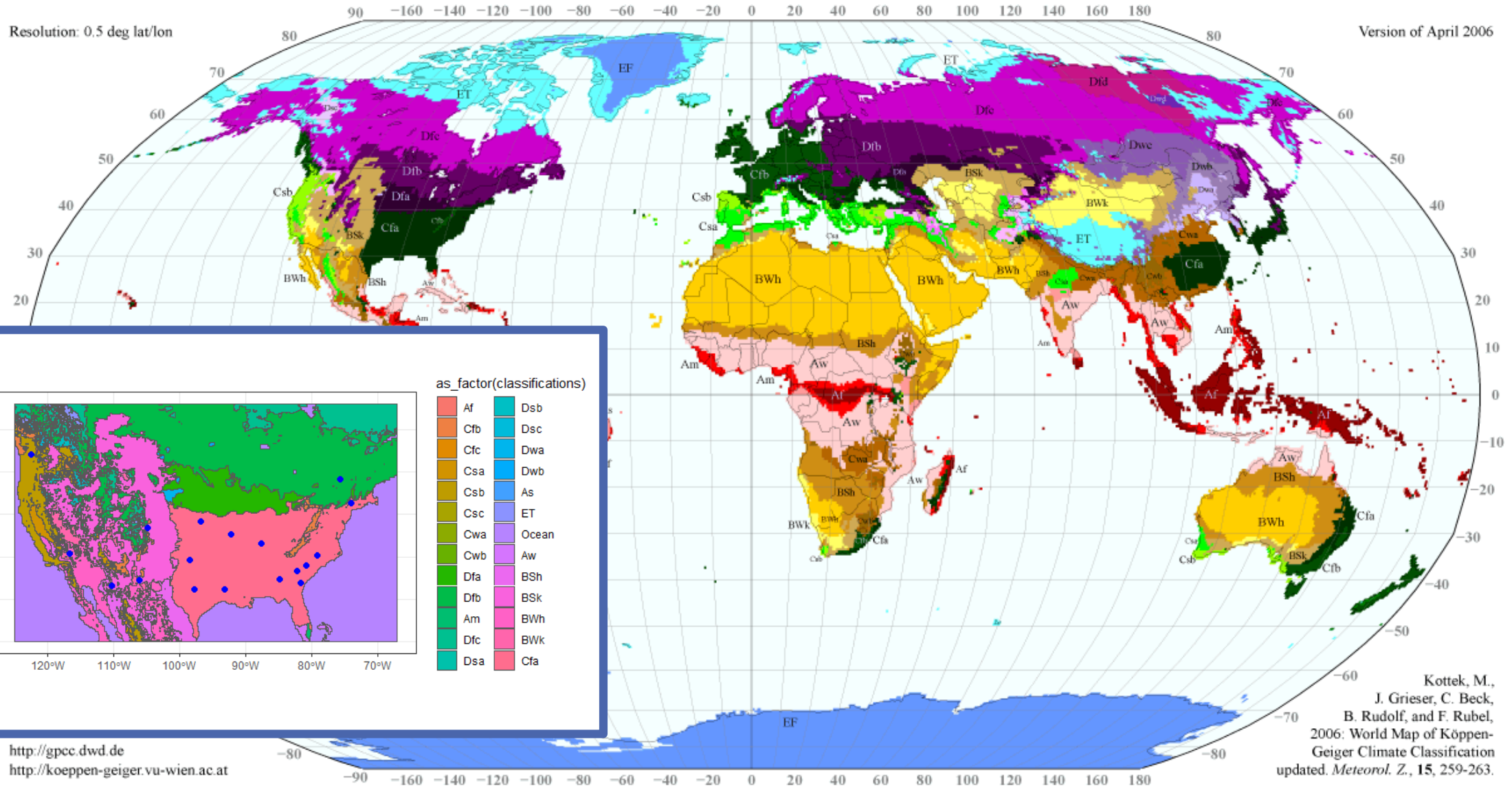
A: equatorial
B: arid
C: warm temperate
D: snow
E: polar

Precipitation

W: desert
S: steppe
f: fully humid
s: summer dry
w: winter dry
m: monsoonal

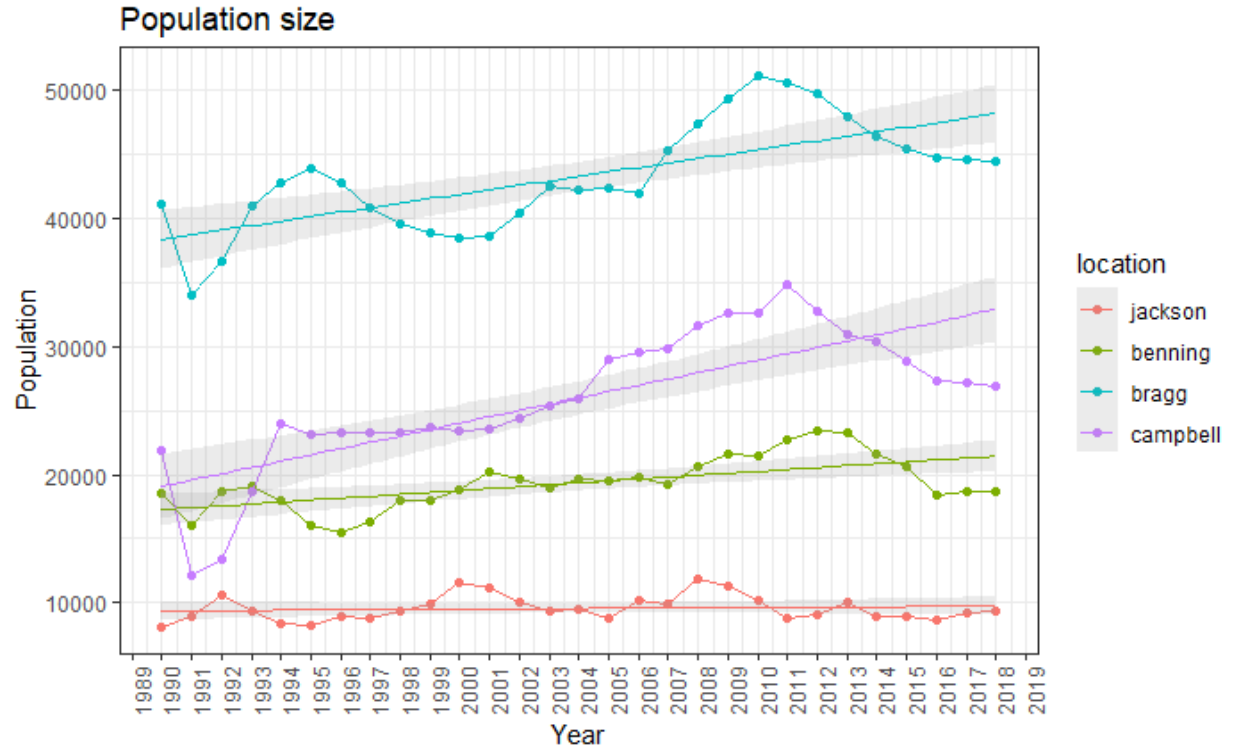
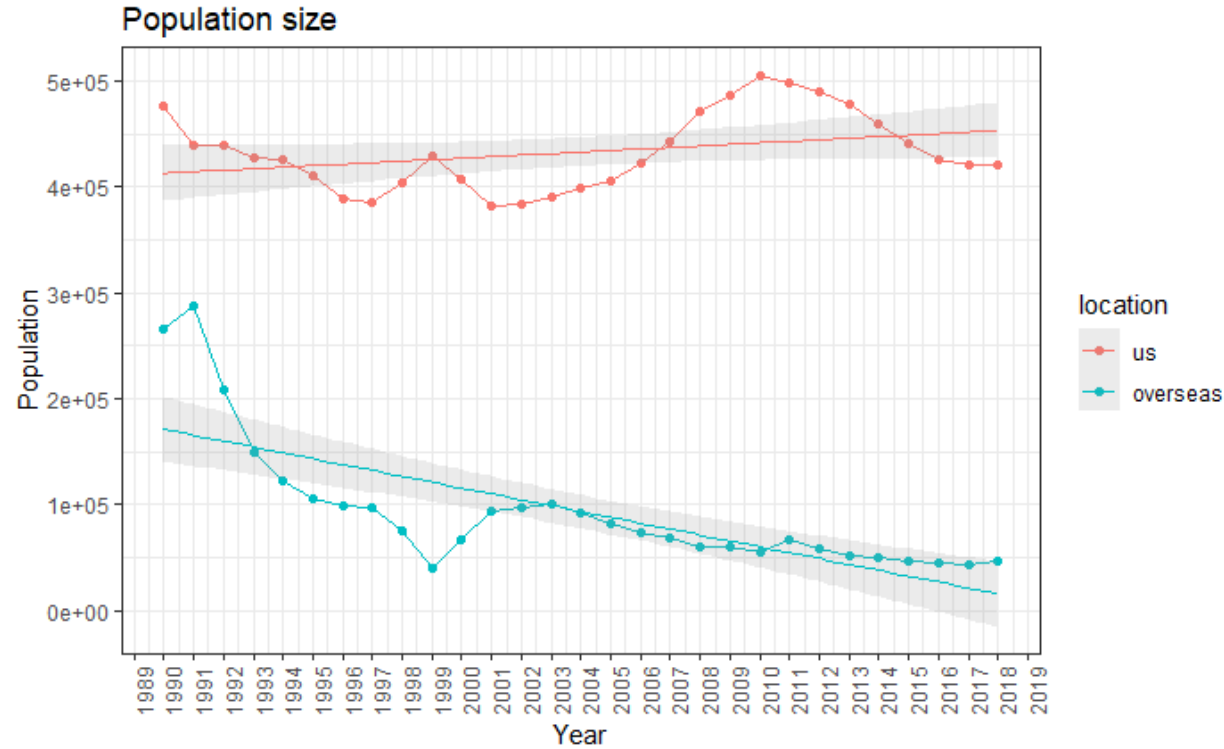
Temperature

h: hot arid
k: cold arid
a: hot summer
b: warm summer
c: cool summer
d: extremely continental
F: polar frost
T: polar tundra



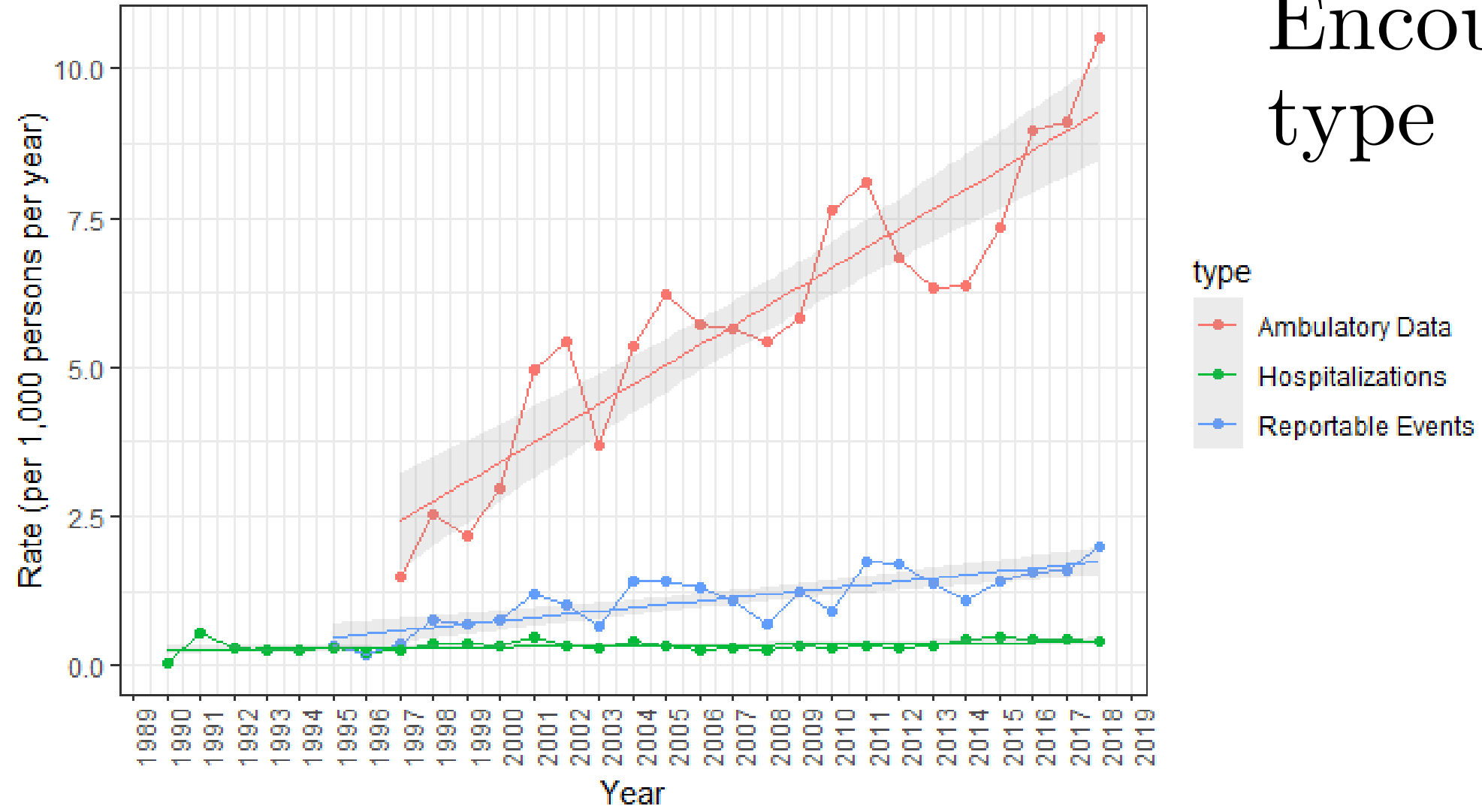
Kottek, M.,
J. Grieser, C. Beck,
B. Rudolf, and F. Rubel,
2006: World Map of Köppen-
Geiger Climate Classification
updated. *Meteorol. Z.*, 15, 259-263.

Population size

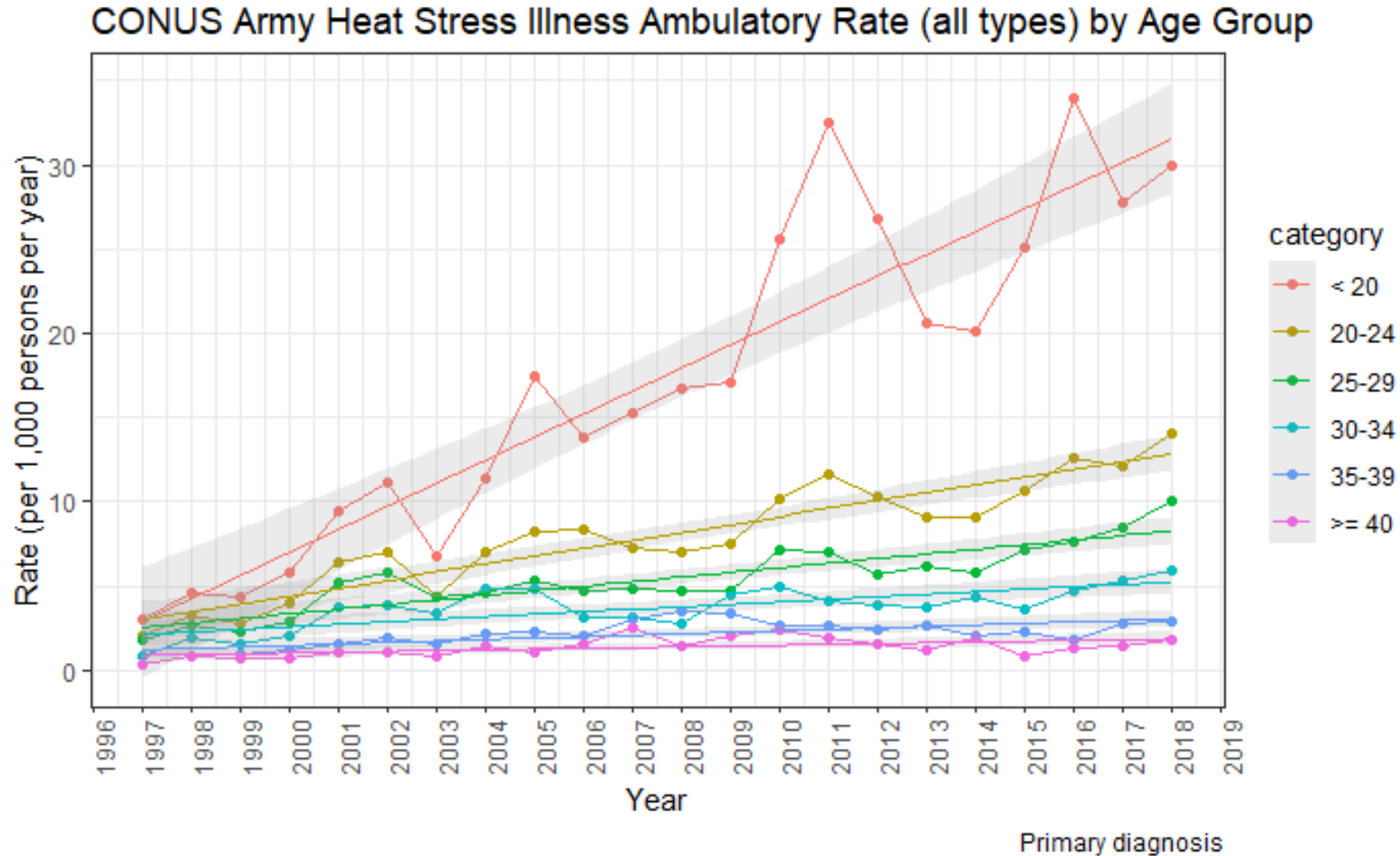


Army Heat Stress Illness Rate (all types) in CONUS

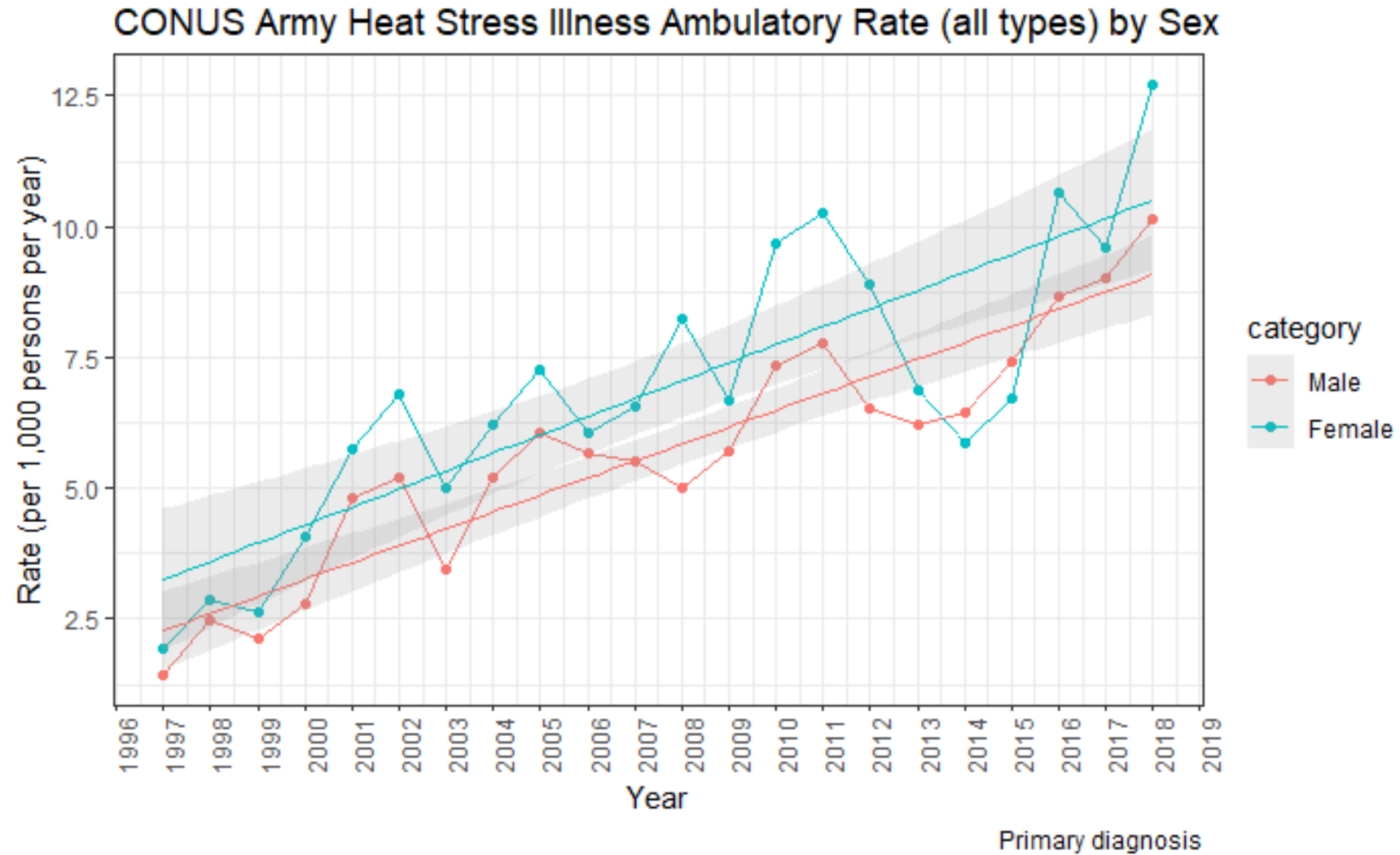
Encounter
type



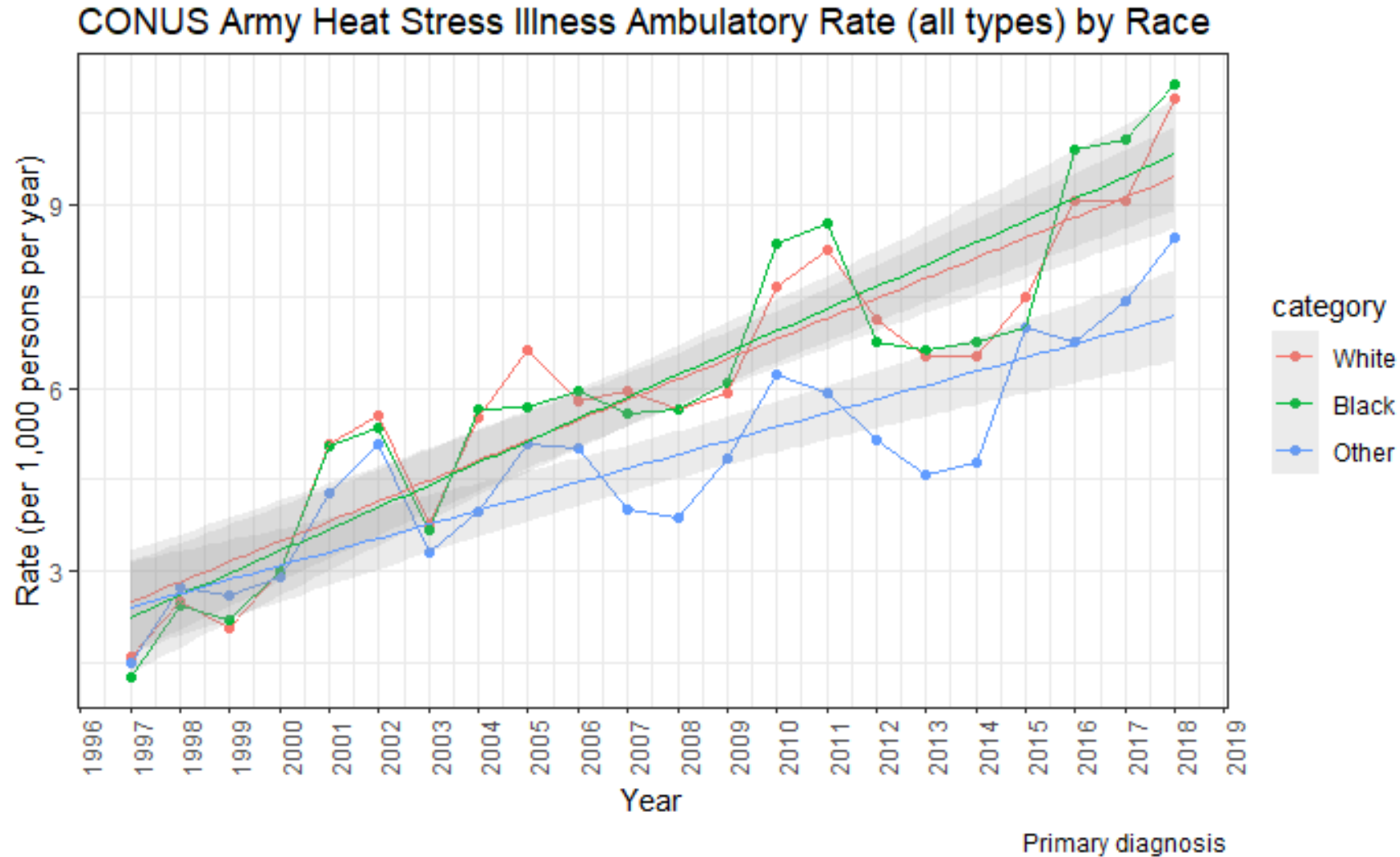
Demographics – Age Group



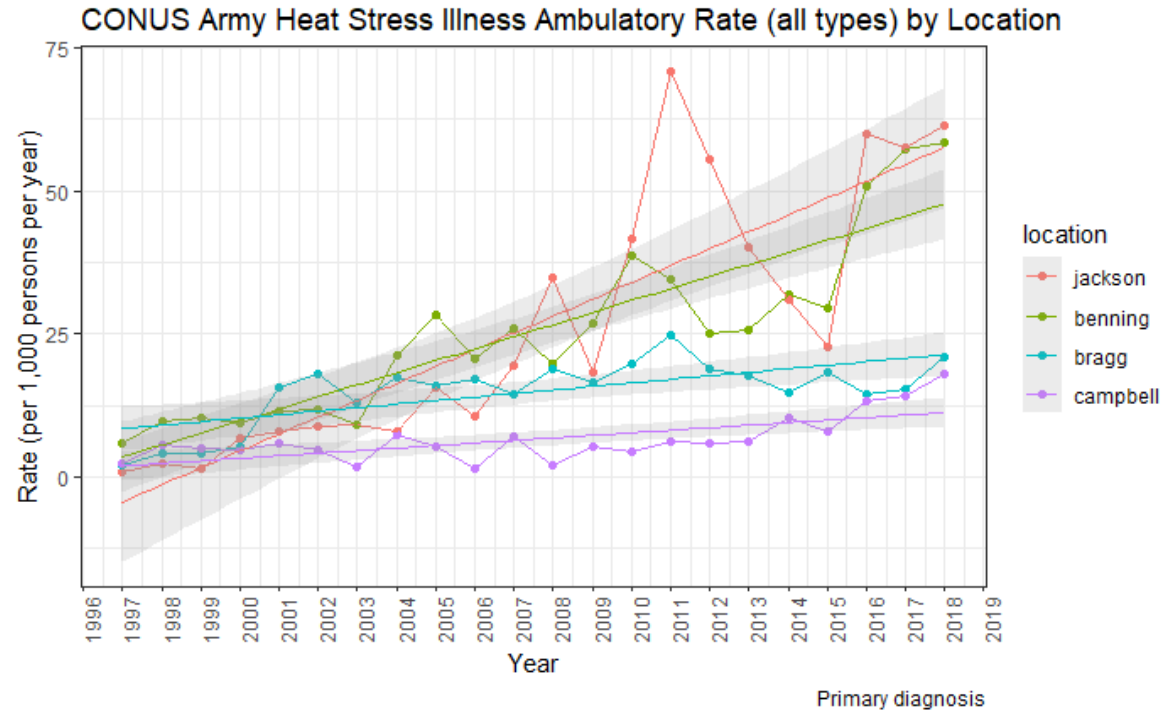
Demographics – Sex



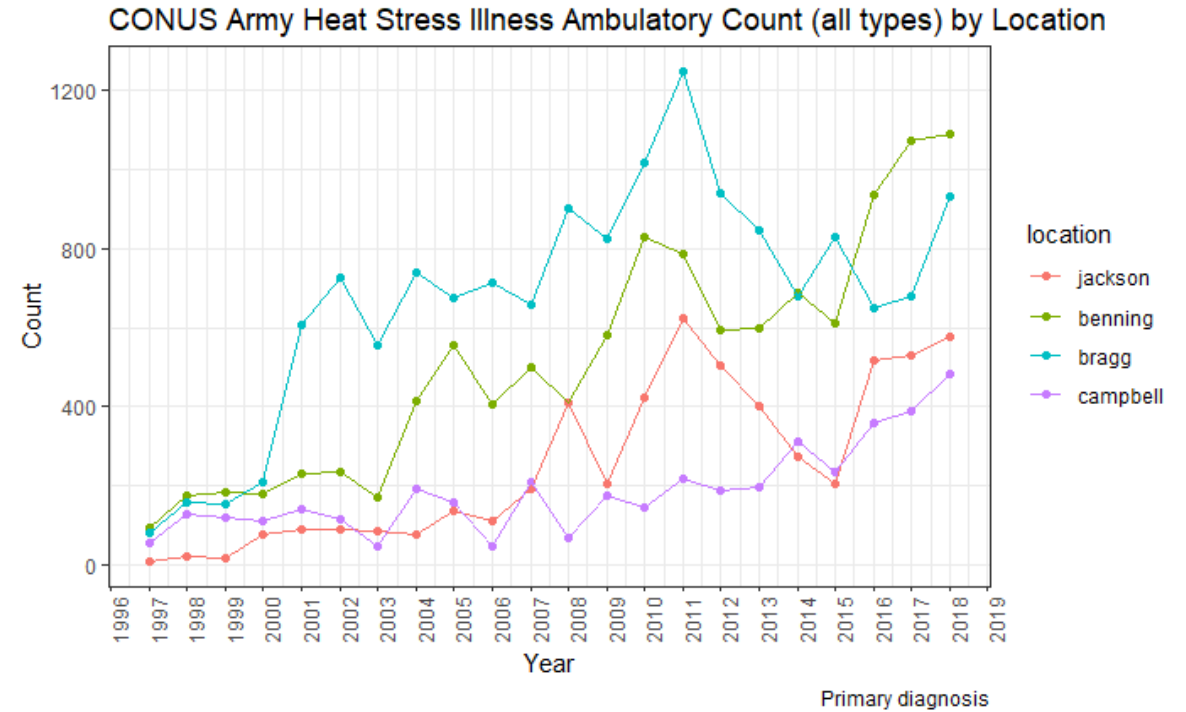
Demographics – Race/Ethnicity



Locations

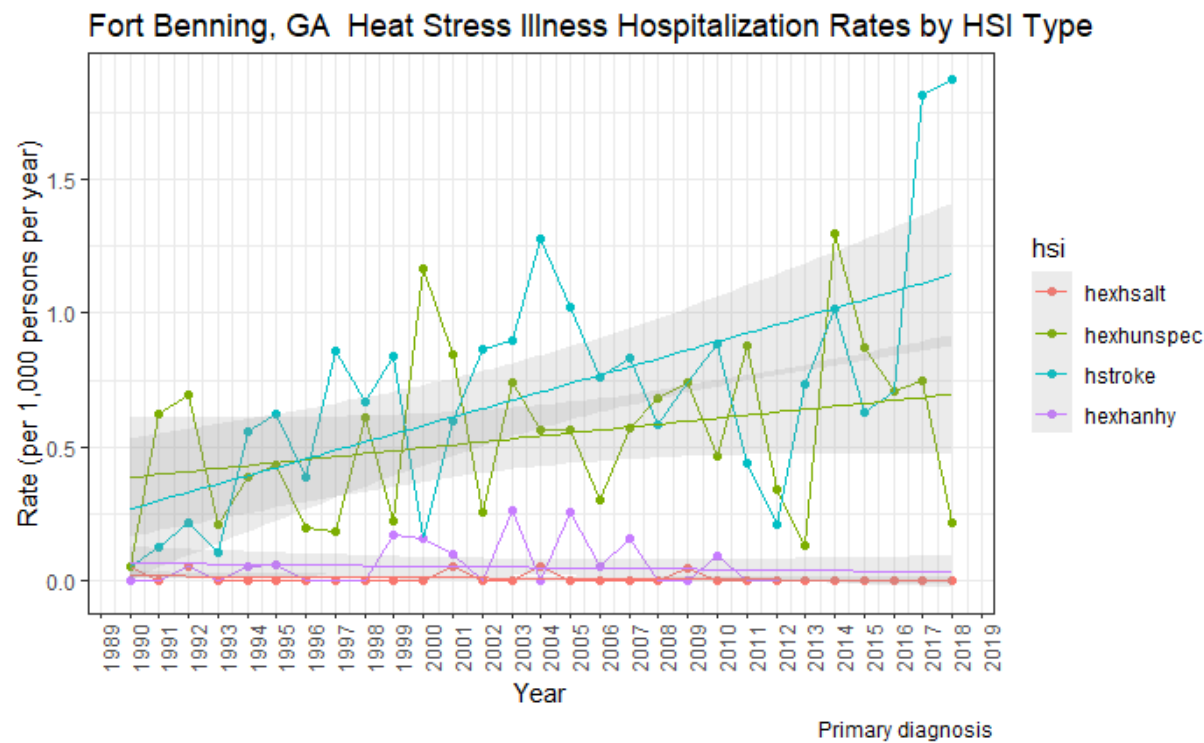
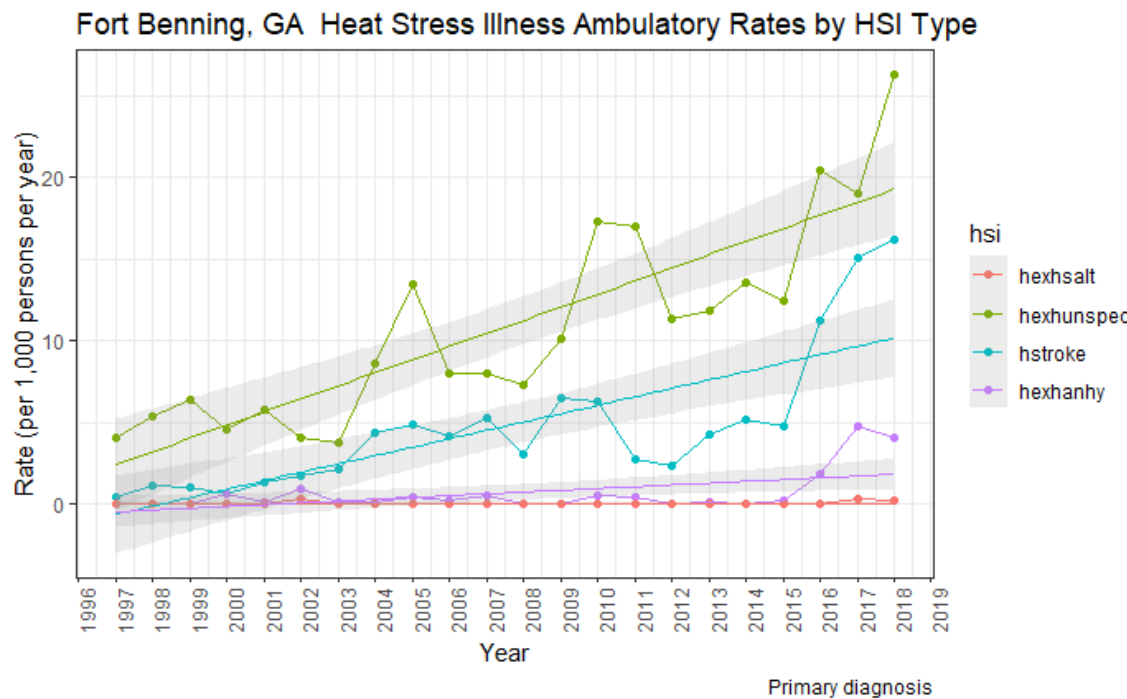


Rates



Counts

Fort Benning, GA



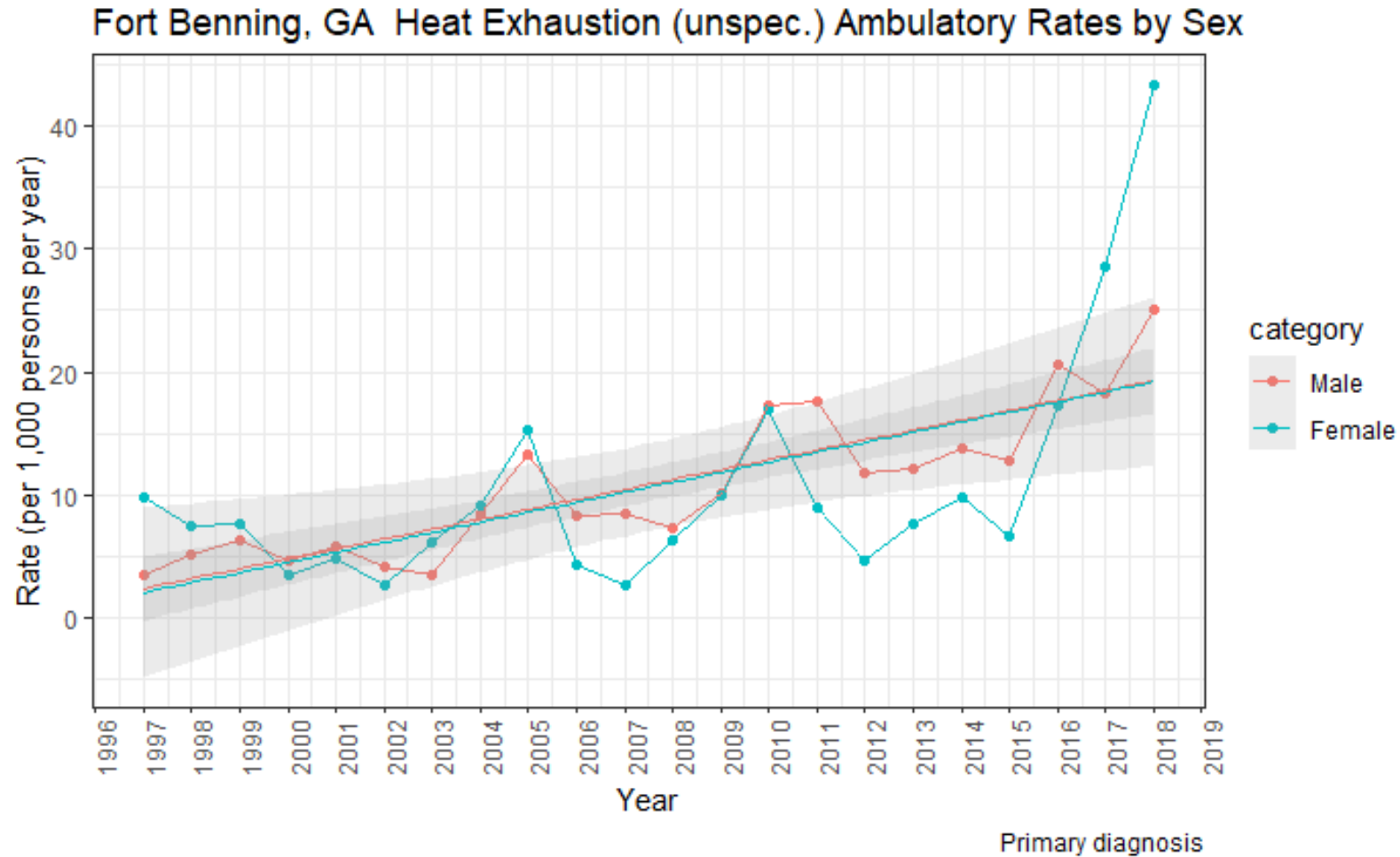
Hospitalizations

Ambulatory

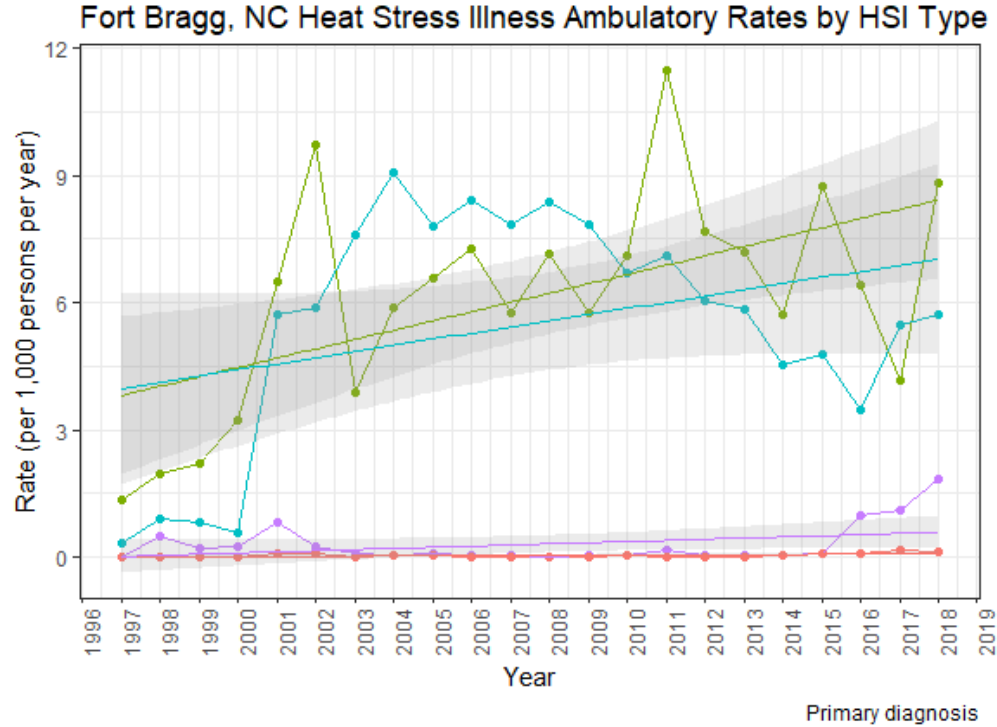
Fort Benning Hospitalization counts

hsi	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
hexhsalt	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
hexhunspec	1	10	13	4	7	7	3	3	11	4	22	17	5	14	11	11	6	11	14	16	10	20	8	3	28	18	13	14	4
hstroke	1	2	4	2	10	10	6	14	12	15	3	12	17	17	25	20	15	16	12	16	19	10	5	17	22	13	13	34	35
hexhanhy	0	0	1	0	1	1	0	0	0	3	3	2	0	5	0	5	1	3	0	0	2	0	0	0	0	0	0	0	0

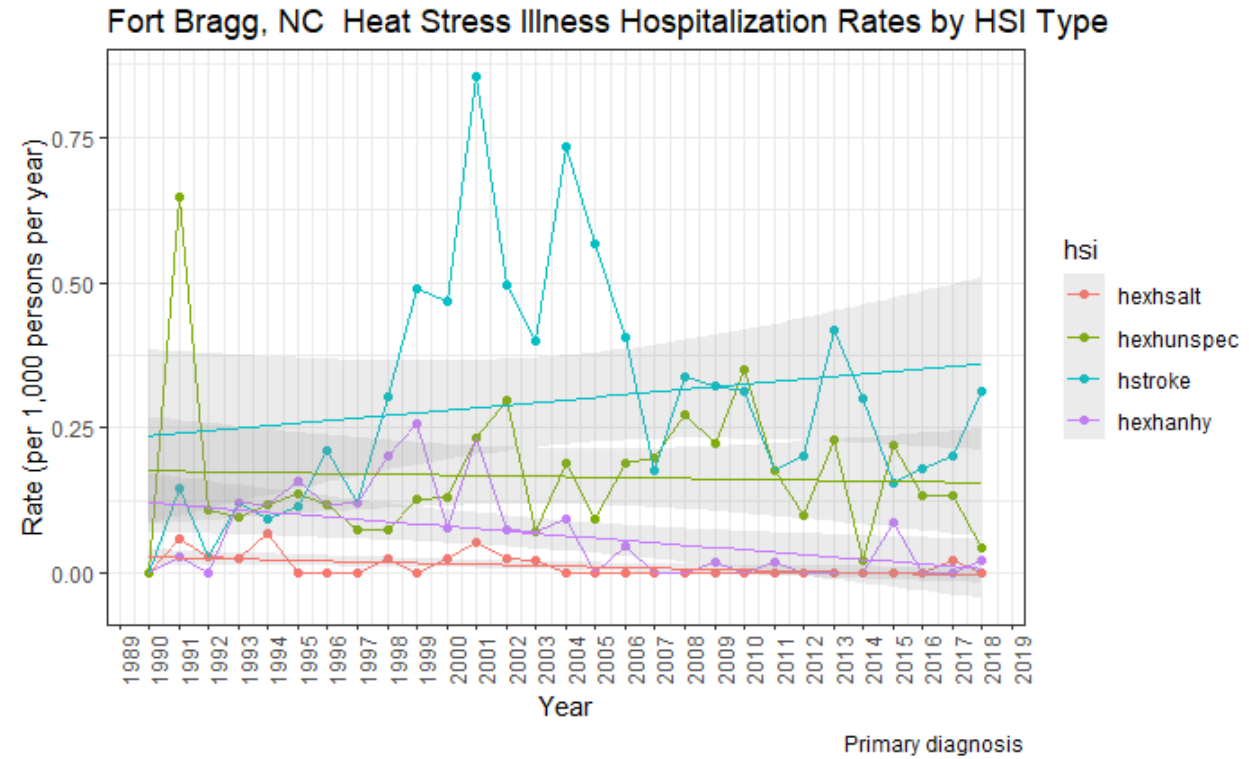
Fort Benning, GA – By Sex



Fort Bragg, NC



Ambulatory

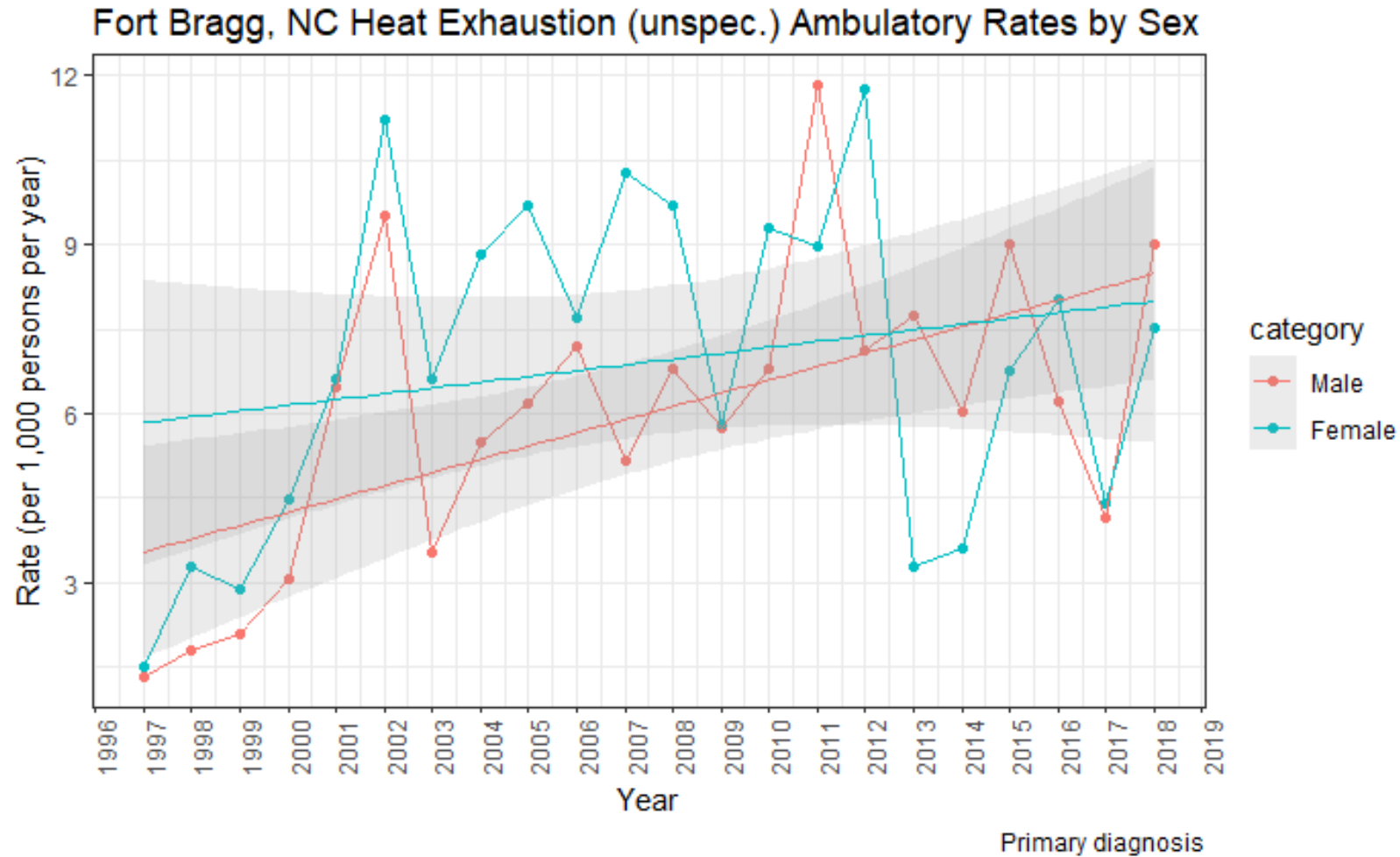


Hospitalizations

Fort Bragg Hospitalization counts

hsi	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
hexhsalt	0	2	1	1	3	0	0	0	1	0	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
hexhunspec	0	22	4	4	5	6	5	3	3	5	5	9	12	3	8	4	8	9	13	11	18	9	5	11	1	10	6	6	2
hstroke	0	5	1	5	4	5	9	5	12	19	18	33	20	17	31	24	17	8	16	16	16	9	10	20	14	7	8	9	14
hexhanhy	0	1	0	5	5	7	5	5	8	10	3	9	3	3	4	0	2	0	0	1	0	1	0	0	0	4	0	0	1

Fort Bragg, NC – By Sex



Discussion: Influencing Factors

- Changes in weather
 - Changes in population demographics, assigned units, deployed units
 - Changes to training timing or intensity
 - Changes in individual susceptibility
 - Changes to prevention strategies
 - Awareness and education
 - Monitoring
 - Commander risk assessments
 - Changes in medical access or coding
-

Next Steps

- Analysis of temperature/heat effects at annual scale
- Data request for daily scale
 - Case-crossover
 - DLNMs