Heat Stress Illness Morbidity in the United States

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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 approached 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 (104ºF/40 ºC), 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)

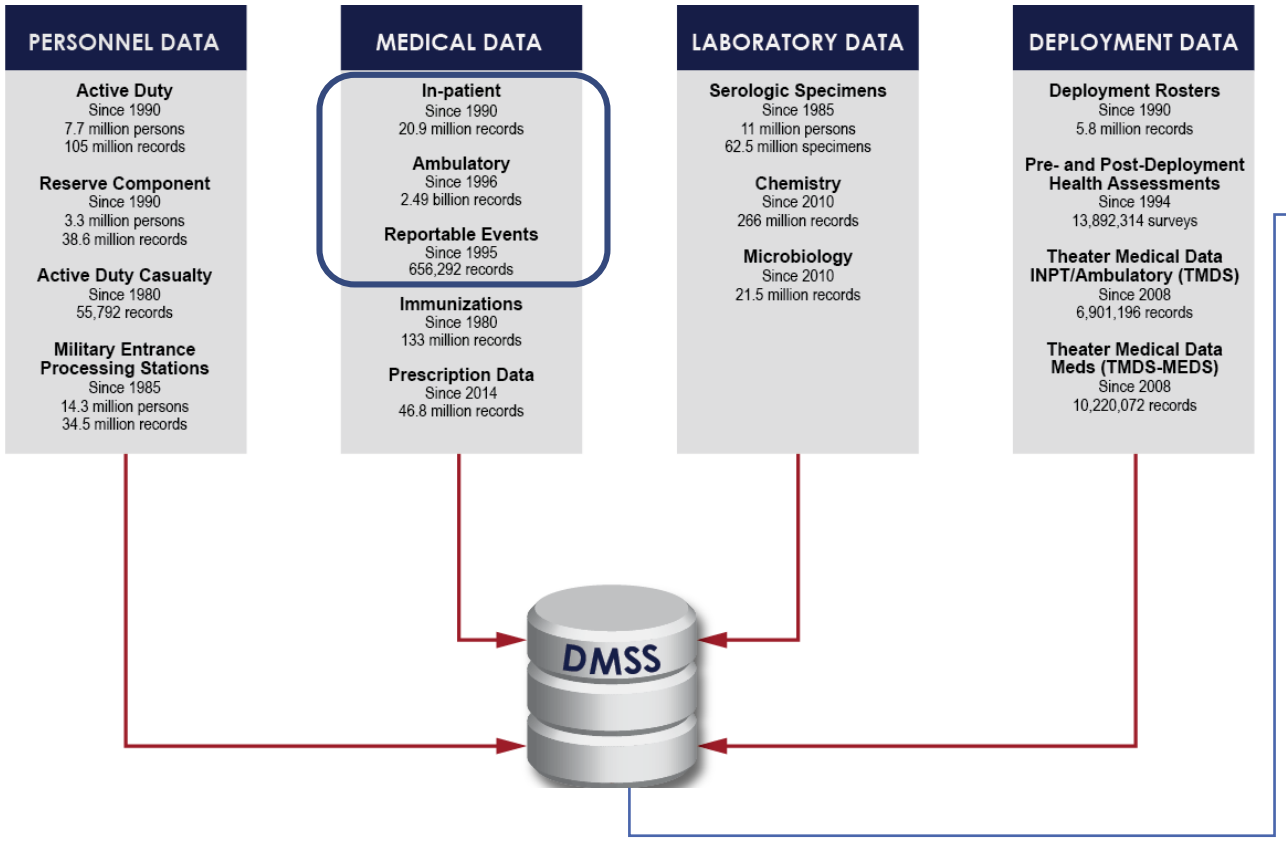
- Heat exhaustion
  - Acute reaction to excessive heat, often accompanied by profuse sweating, dizziness, nausea, headache and fatigue

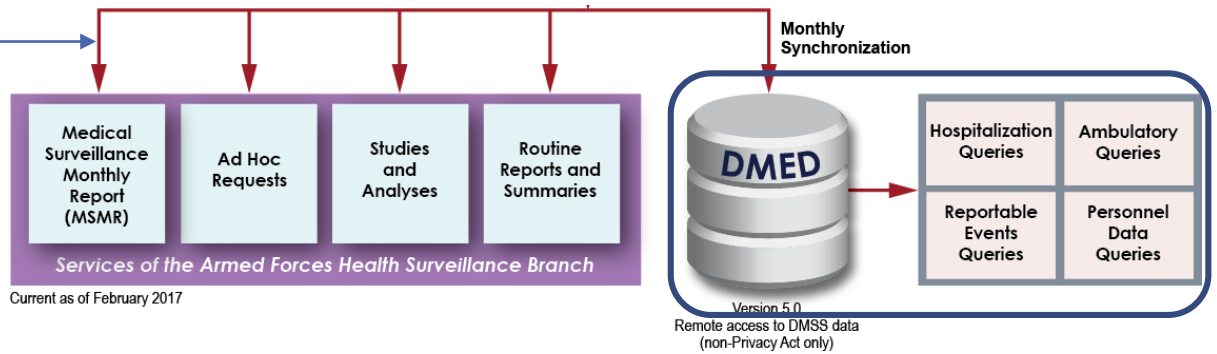
Types
Anhydrotic (due to water depletion)
Due to salt depletion
Unspecified

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





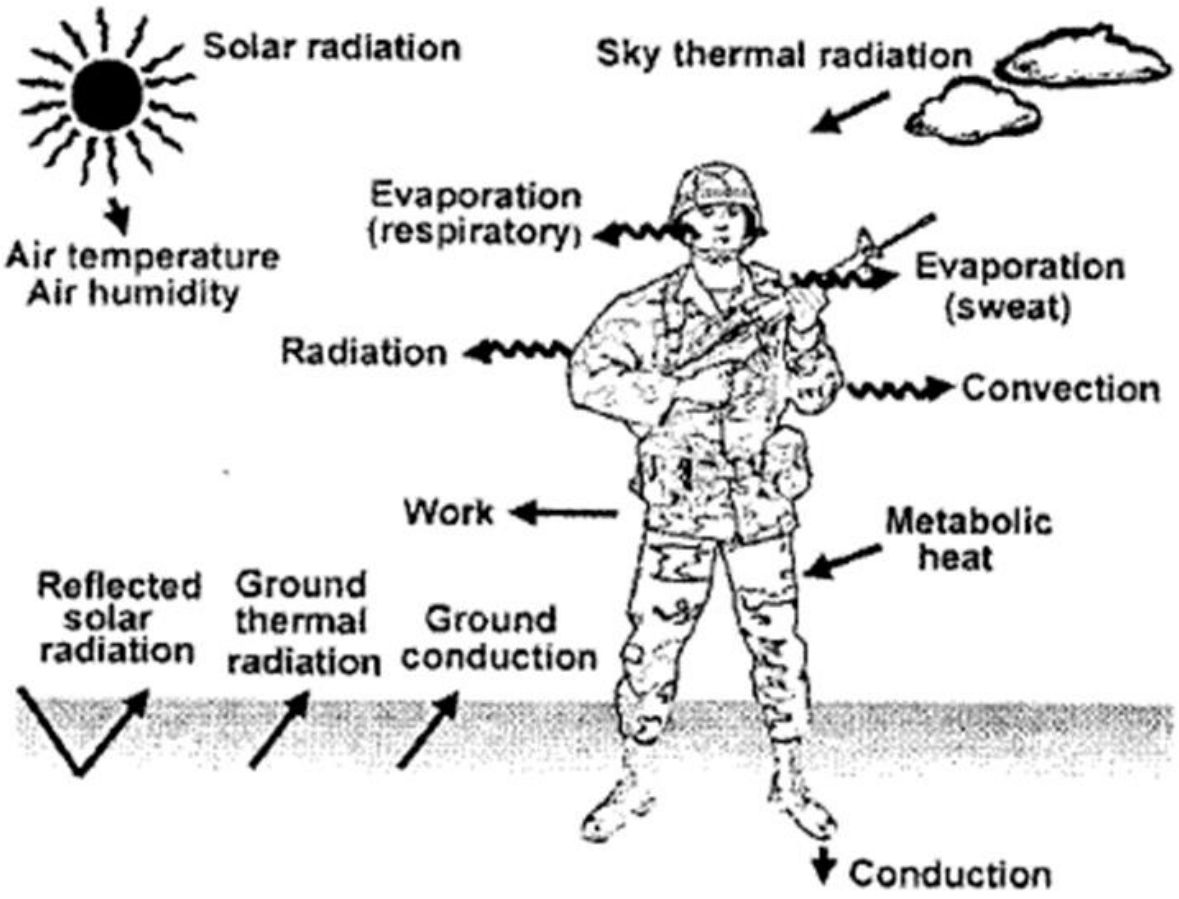
- Hospitalizations (In-patient)
- Ambulatory (Out-patient)

https://www.health.mil/Military-Health-Topics/Combat-Support/Armed-Forces-Health-Surveillance-Branch/Data-Management-and-Technical-Support/Defense-Medical-Surveillance-System

Heat exposure parameters

- Temperature
- Humidity
  - Relative humidity
  - Specific humidity
- Wind Speed
- Solar radiation
  - Sun angle
  - Cloud cover

- Indices: Heat Index, Wet Bulb Globe Temperature



TB MED 507, Heat Stress Control and Heat Casualty Management (2003)

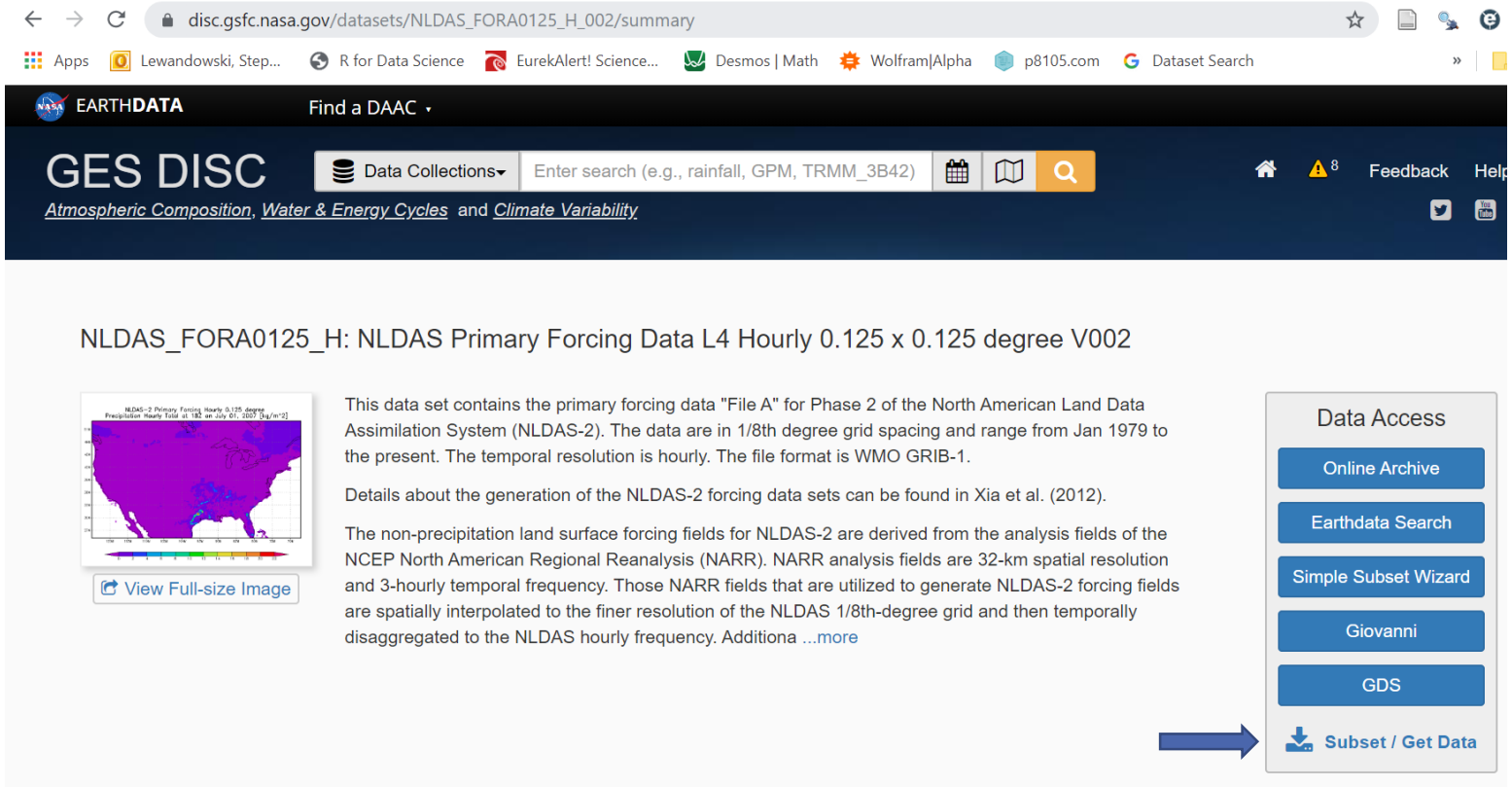
Heat exposure classification approaches

- 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



Get NLDAS Primary Forcing Data L4 Hourly 0.125 x 0.125 degree V002 data

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/m^2)
- 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/m^2)
- DSWRF = Shortwave radiation flux downwards (surface) (W/m^2)
- PEVAP = Potential evaporation hourly total (kg/m^2)
- 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 Reset

- GRIB (Default)
- NetCDF

Reset All | Get Data

Lab group

Data File Links for NLDAS Primary Forcing Data L4 Hourly 0.125 x 0.125 degree V002

Results:

Searching for data... (1%)

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

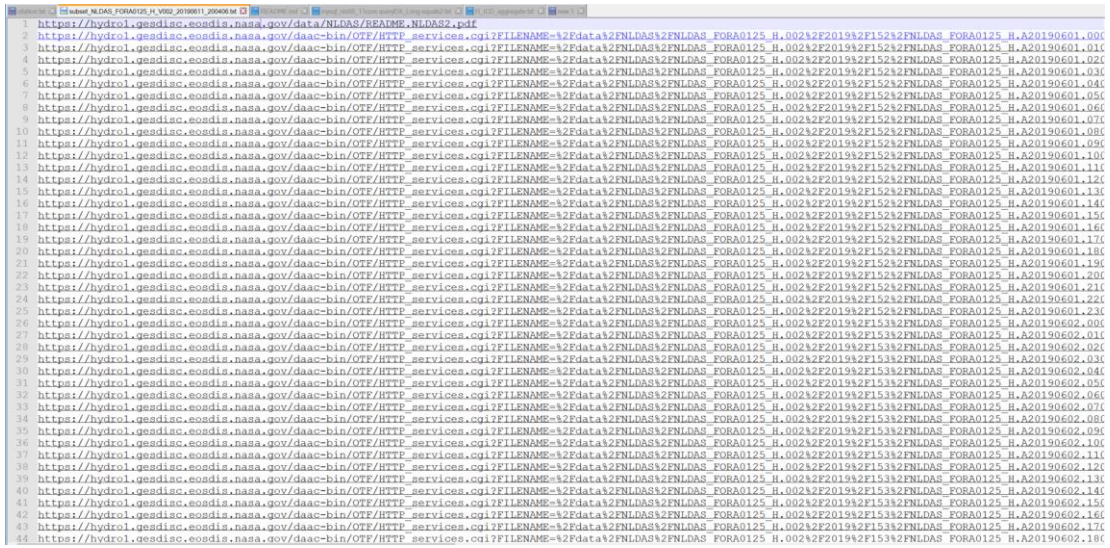
Download links list * (This list is valid for **2** days) | Instructions for downloading

README Document
NLDAS_FORA0125_H.A19790101.1300.002.grb.SUB.nc4
NLDAS_FORA0125_H.A19790101.1400.002.grb.SUB.nc4
NLDAS_FORA0125_H.A19790101.1500.002.grb.SUB.nc4
NLDAS_FORA0125_H.A19790101.1600.002.grb.SUB.nc4
NLDAS_FORA0125_H.A19790101.1700.002.grb.SUB.nc4
NLDAS_FORA0125_H.A19790101.1800.002.grb.SUB.nc4
NLDAS_FORA0125_H.A19790101.1900.002.grb.SUB.nc4
NLDAS_FORA0125_H.A19790101.2000.002.grb.SUB.nc4

Selected Parameters

Cancel request

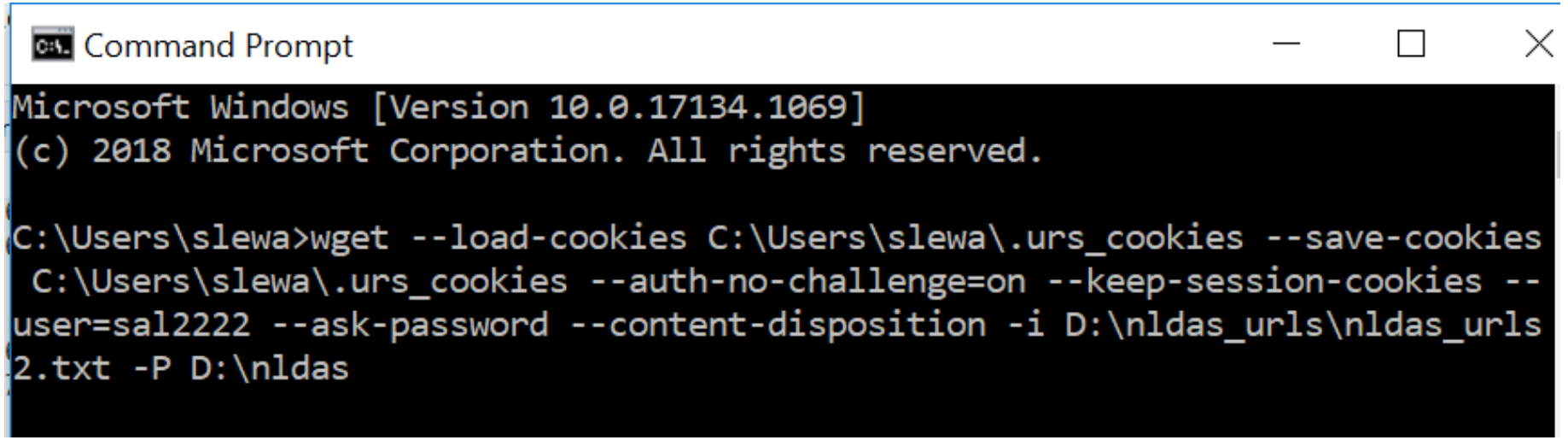
Job ID: 5dbb0485fbcdba5200ce881a



NLDAS-2 Workflow (cont.)

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

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



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")
```

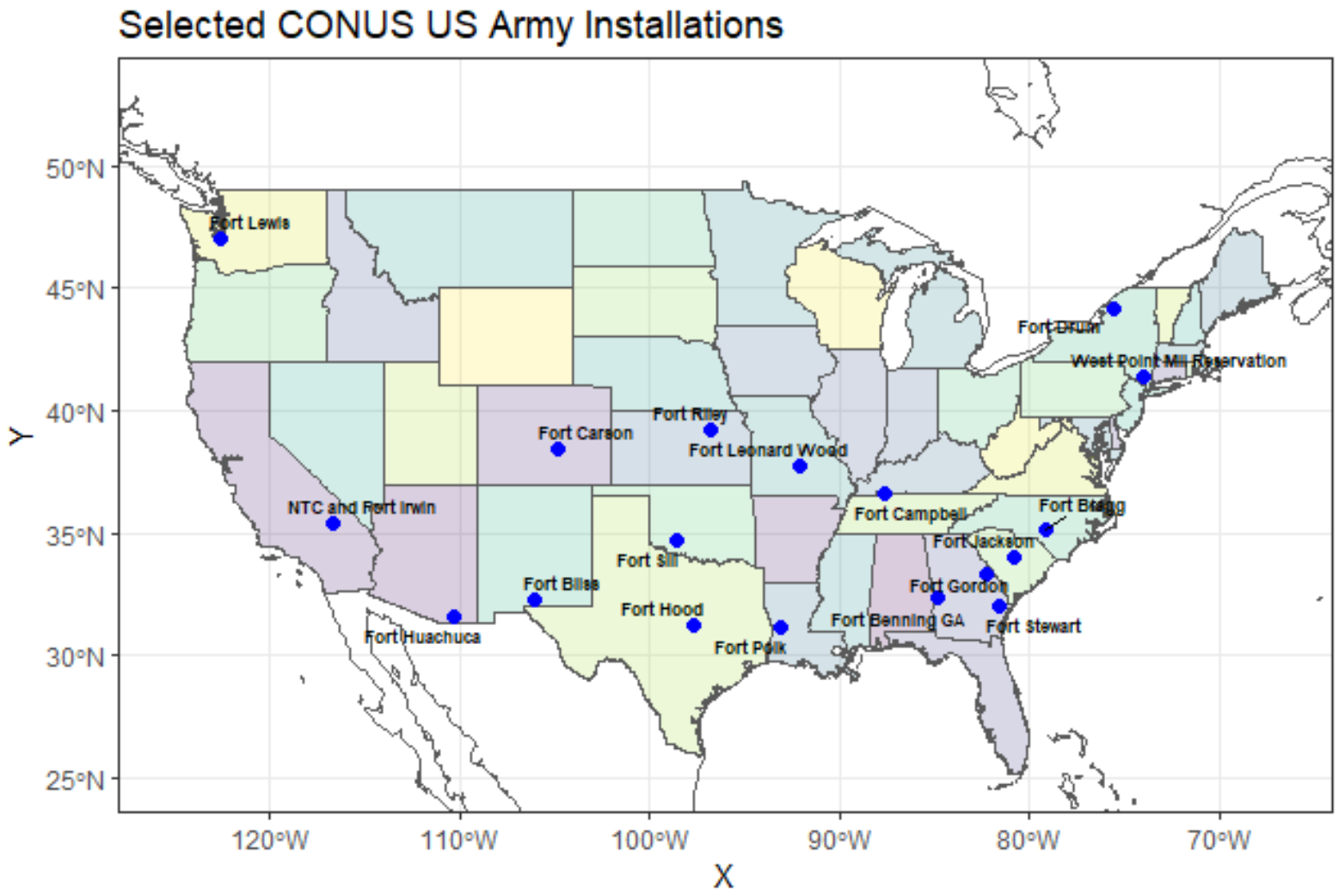
NLDAS-2 Workflow (cont.)

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                          cells
 [1,] "Fort Benning GA"              "76418"
 [2,] "Fort Campbell"                "61084"
 [3,] "Fort Huachuca"                "79462"
 [4,] "Fort Riley"                   "51266"
 [5,] "NTC and Fort Irwin"           "65491"
 [6,] "Fort Gordon"                  "73191"
 [7,] "Fort Sill"                    "67956"
 [8,] "Fort Carson"                  "53986"
 [9,] "Fort Lewis"                   "21828"
[10,] "Fort Bragg"                   "66255"
[11,] "West Point Mil Reservation"   "43560"
[12,] "Fort Polk"                    "80992"
[13,] "Fort Jackson"                 "70418"
[14,] "Fort Leonard Wood"            "56871"
[15,] "Fort Bliss"                   "76712"
[16,] "Fort Hood"                    "80955"
[17,] "Fort Drum"                    "33340"
[18,] "Fort Stewart"                 "78300"
```

U.S. Army Background HSI




```
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

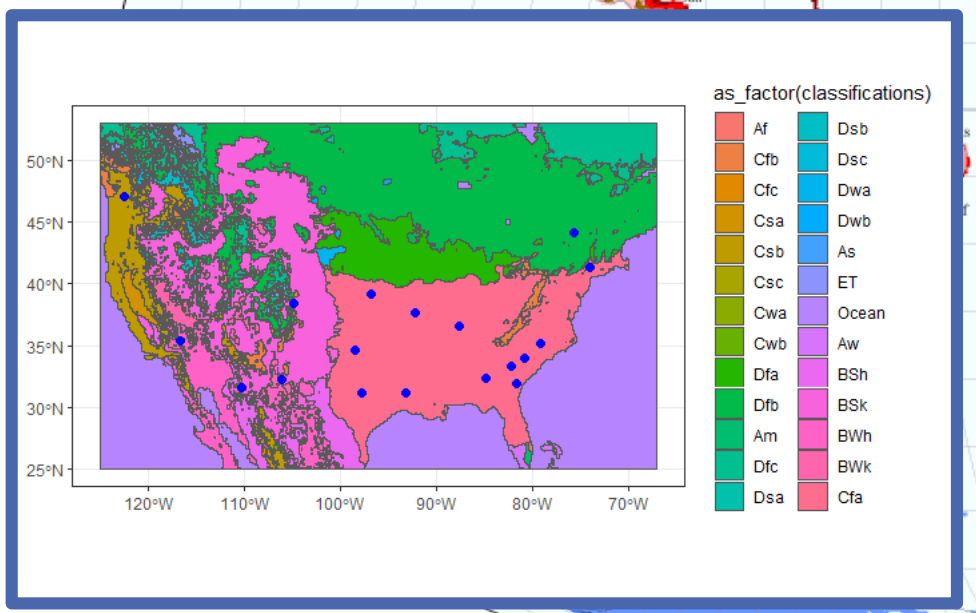
Main climates	Precipitation	Temperature	
A: equatorial	W: desert	h: hot arid	F: polar frost
B: arid	S: steppe	k: cold arid	T: polar tundra
C: warm temperate	f: fully humid	a: hot summer	
D: snow	s: summer dry	b: warm summer	
E: polar	w: winter dry	c: cool summer	
	m: monsoonal	d: extremely continental	

Af Am As Aw BWk BWh BSk BSh Cfa Cfb Cfc Csa Csb Csc Cwa

Cwb Cwc Dfa Dfb Dfc Dfd Dsa Dsb Dsc Dsd Dwa Dwb Dwc Dwd EF ET

Resolution: 0.5 deg lat/lon

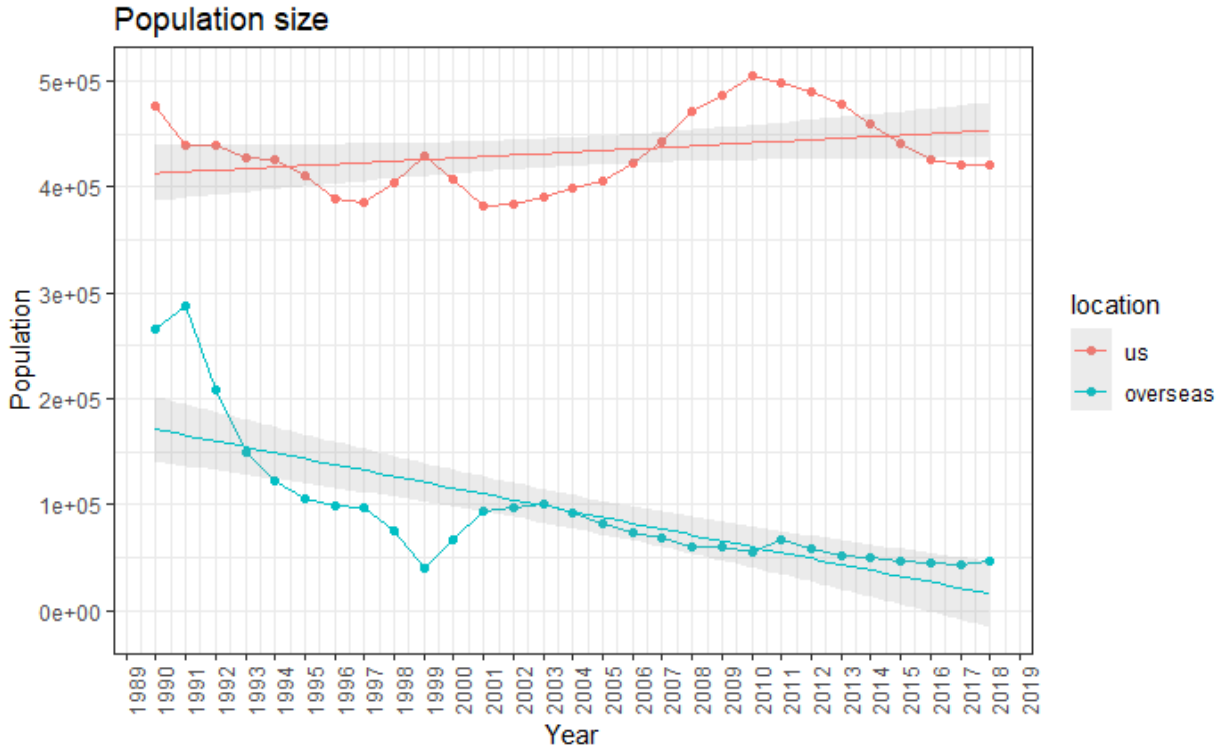
Version of April 2006

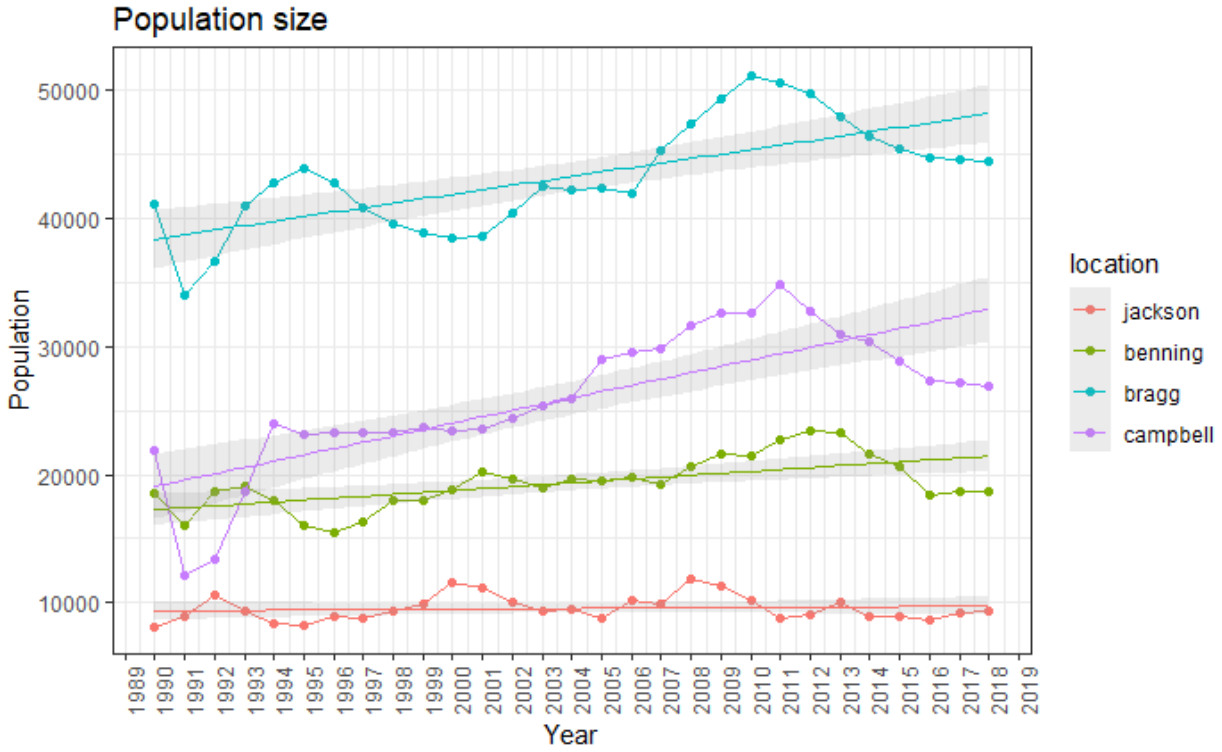


http://gpcc.dwd.de
http://koeppen-geiger.vu-wien.ac.at

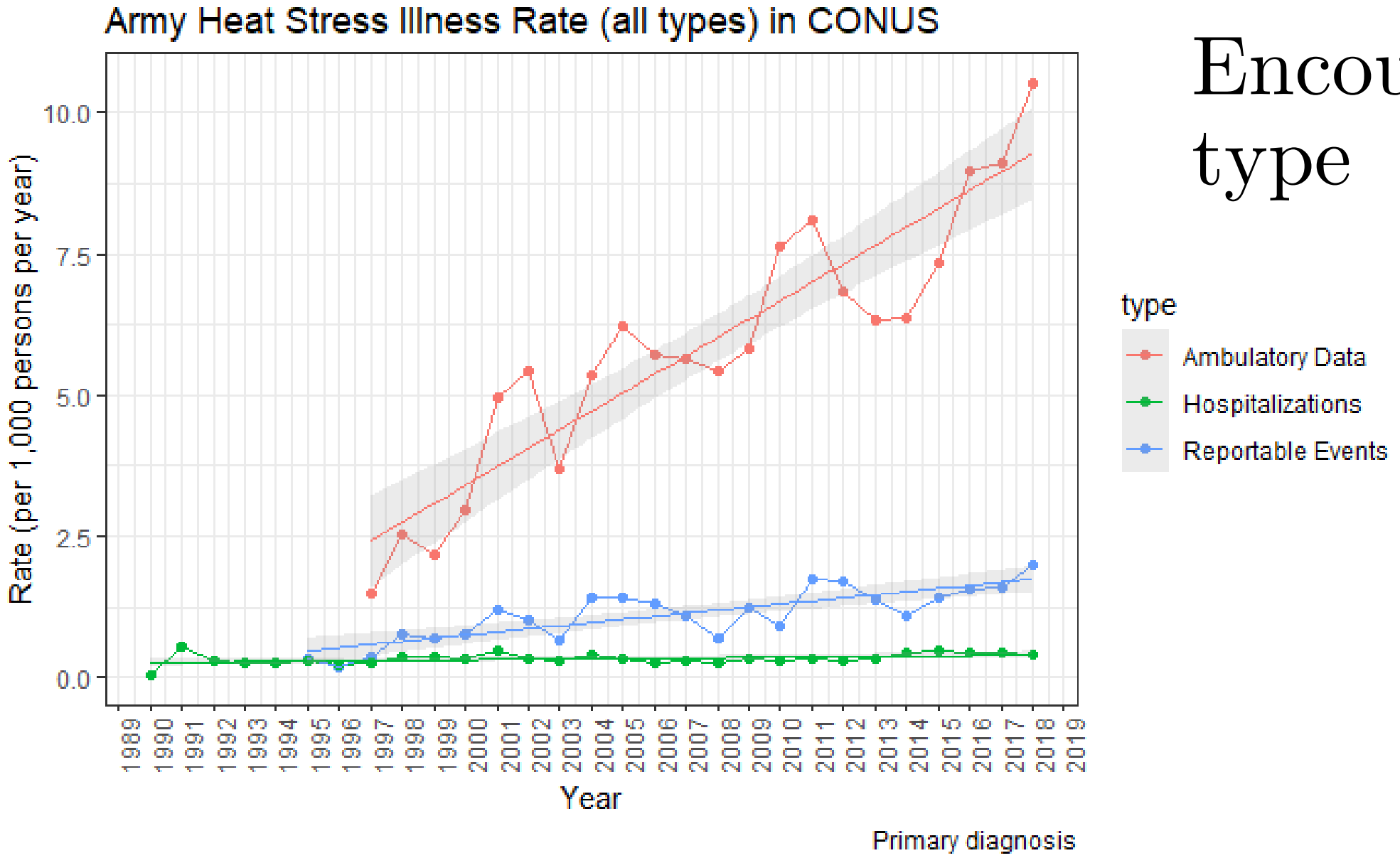
Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of Köppen-Geiger Climate Classification updated. *Meteorol. Z.*, **15**, 259-263.

Population size

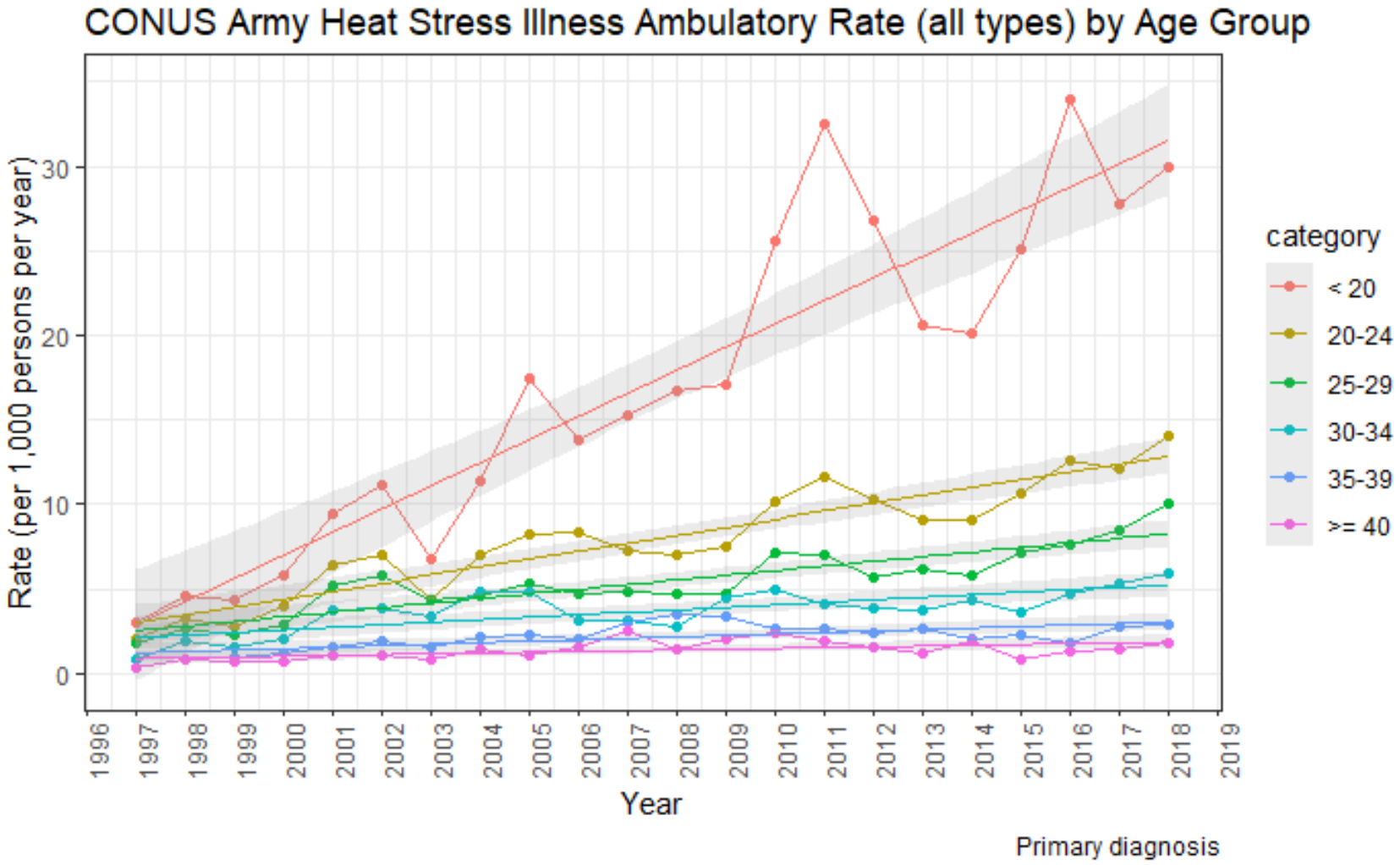




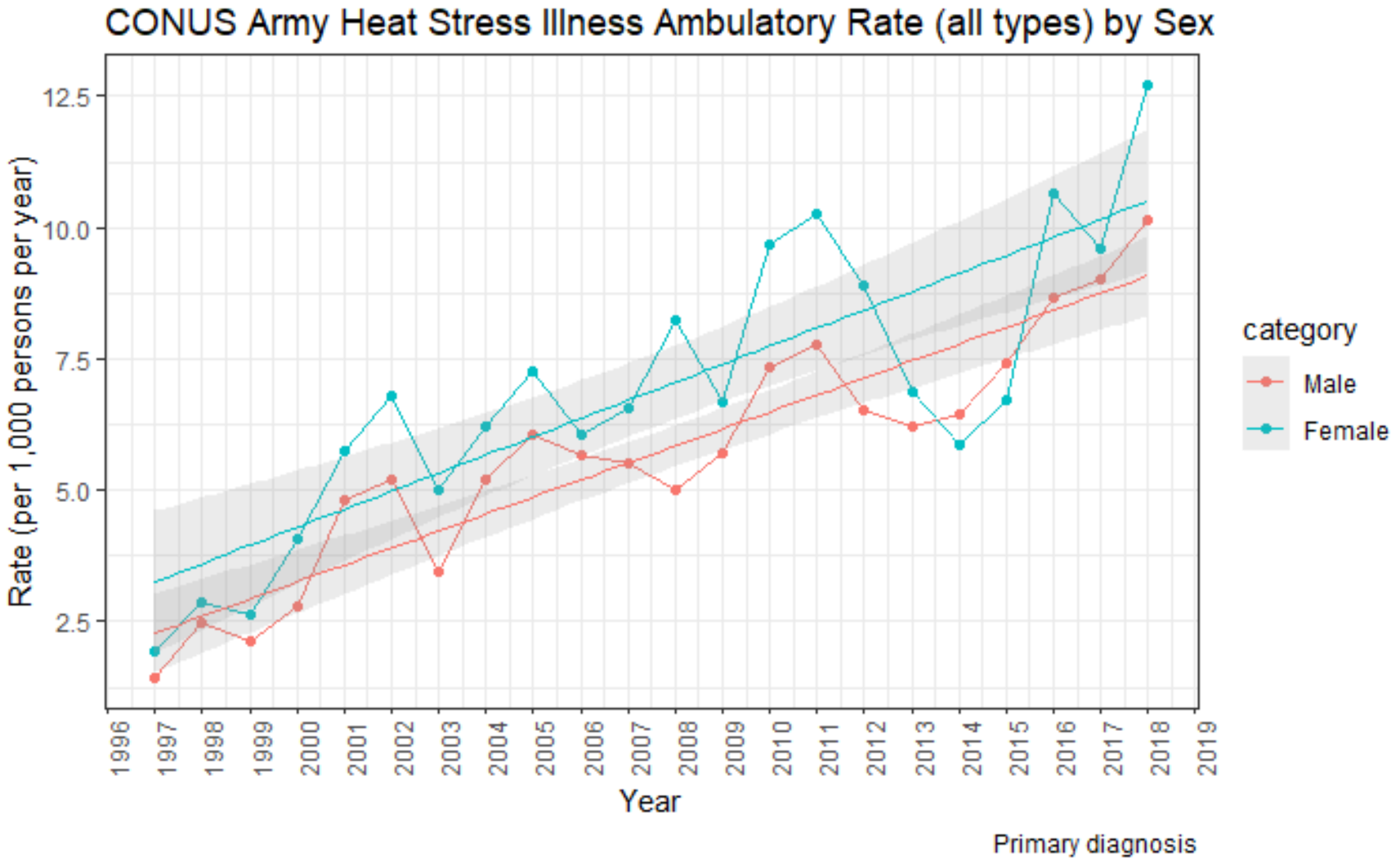
Encounter type



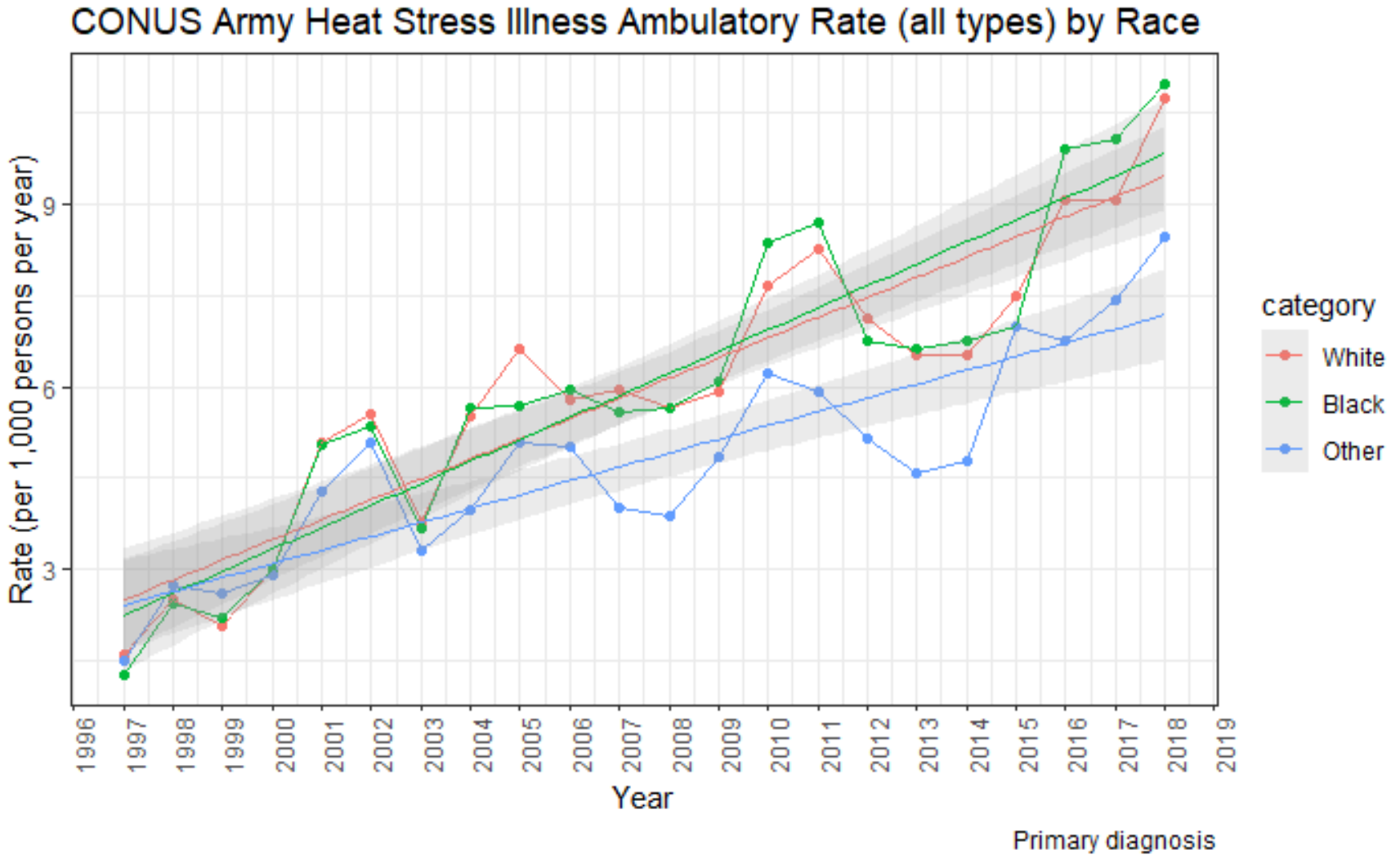
Demographics – Age Group



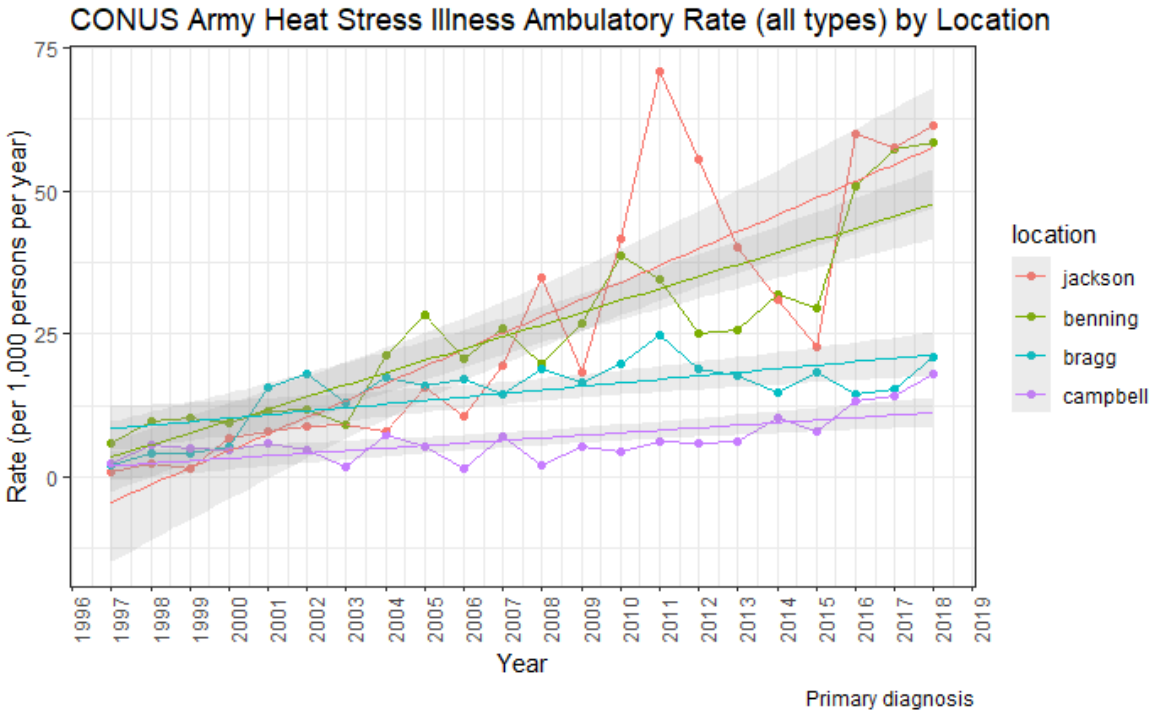
Demographics – Sex



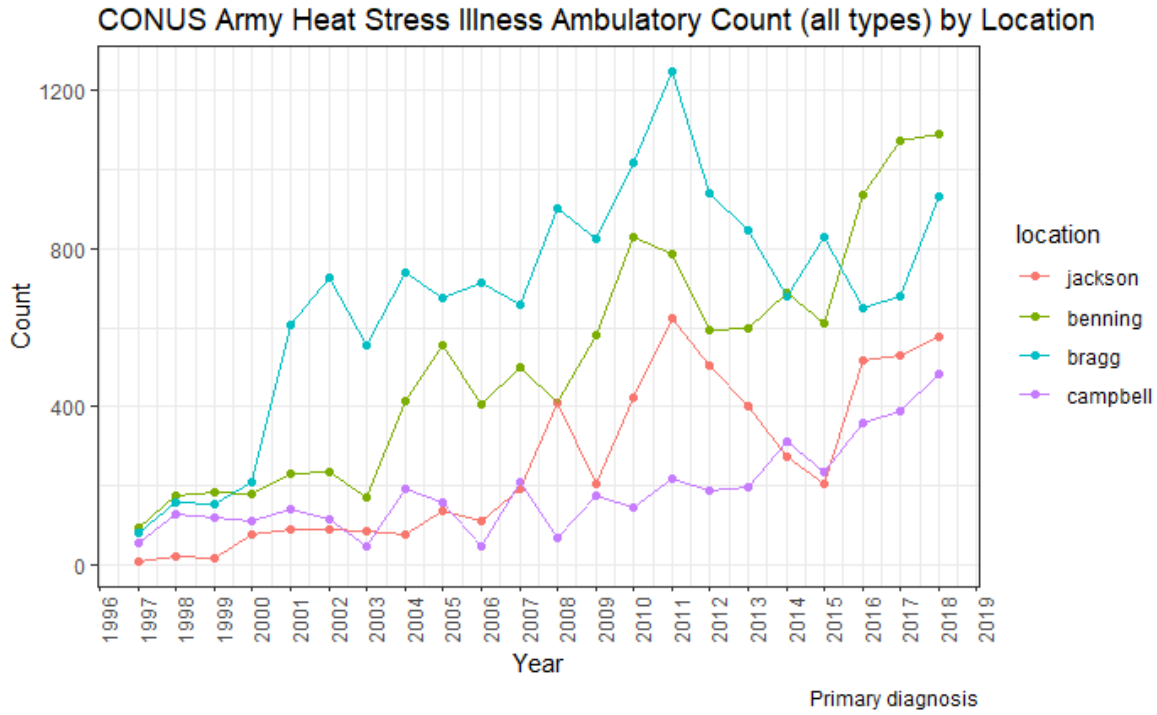
Demographics – Race/Ethnicity



Locations

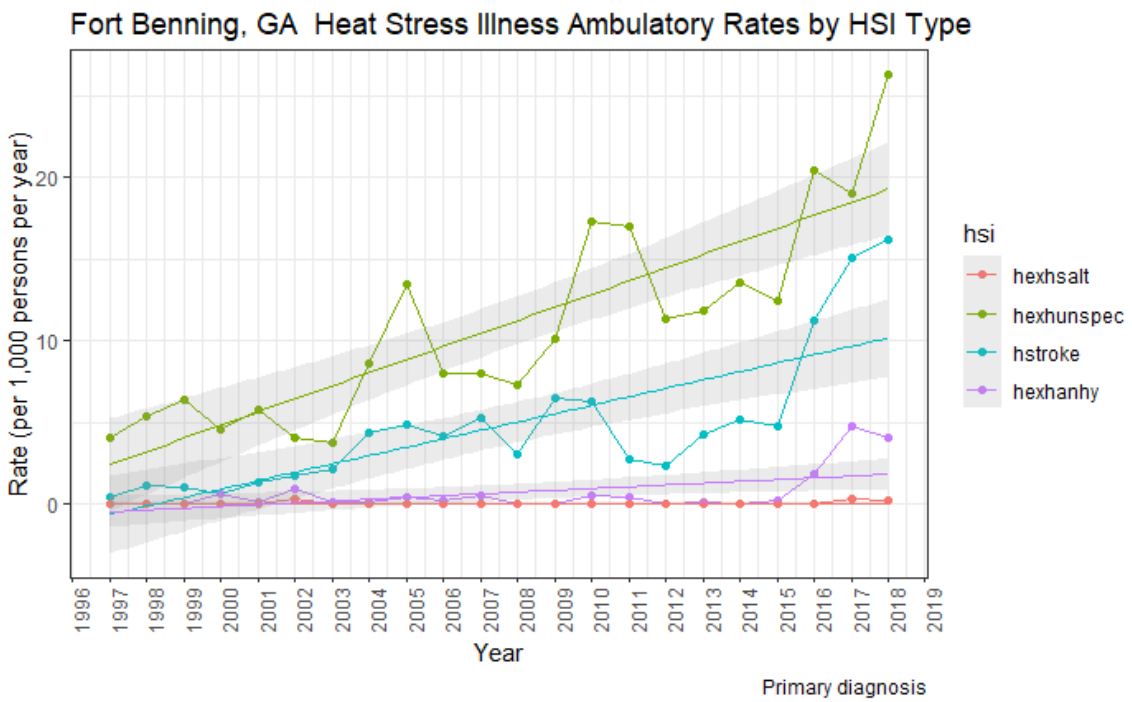


Rates

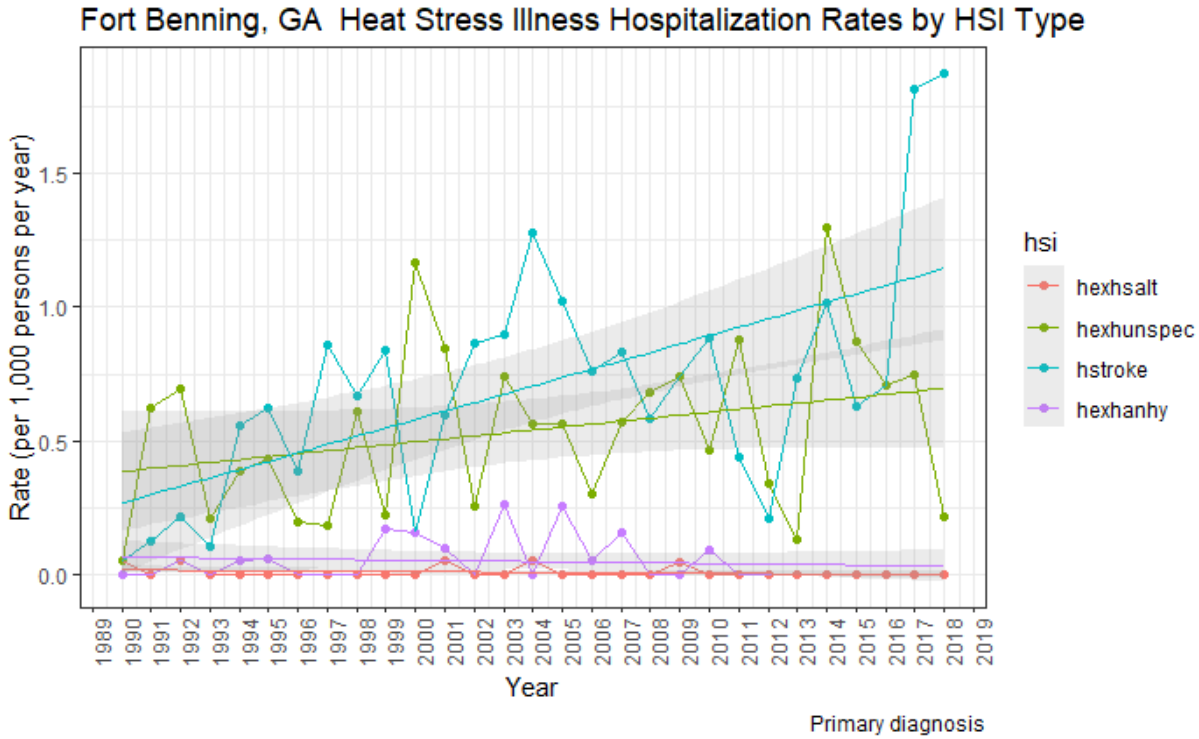


Counts

Fort Benning, GA



Ambulatory

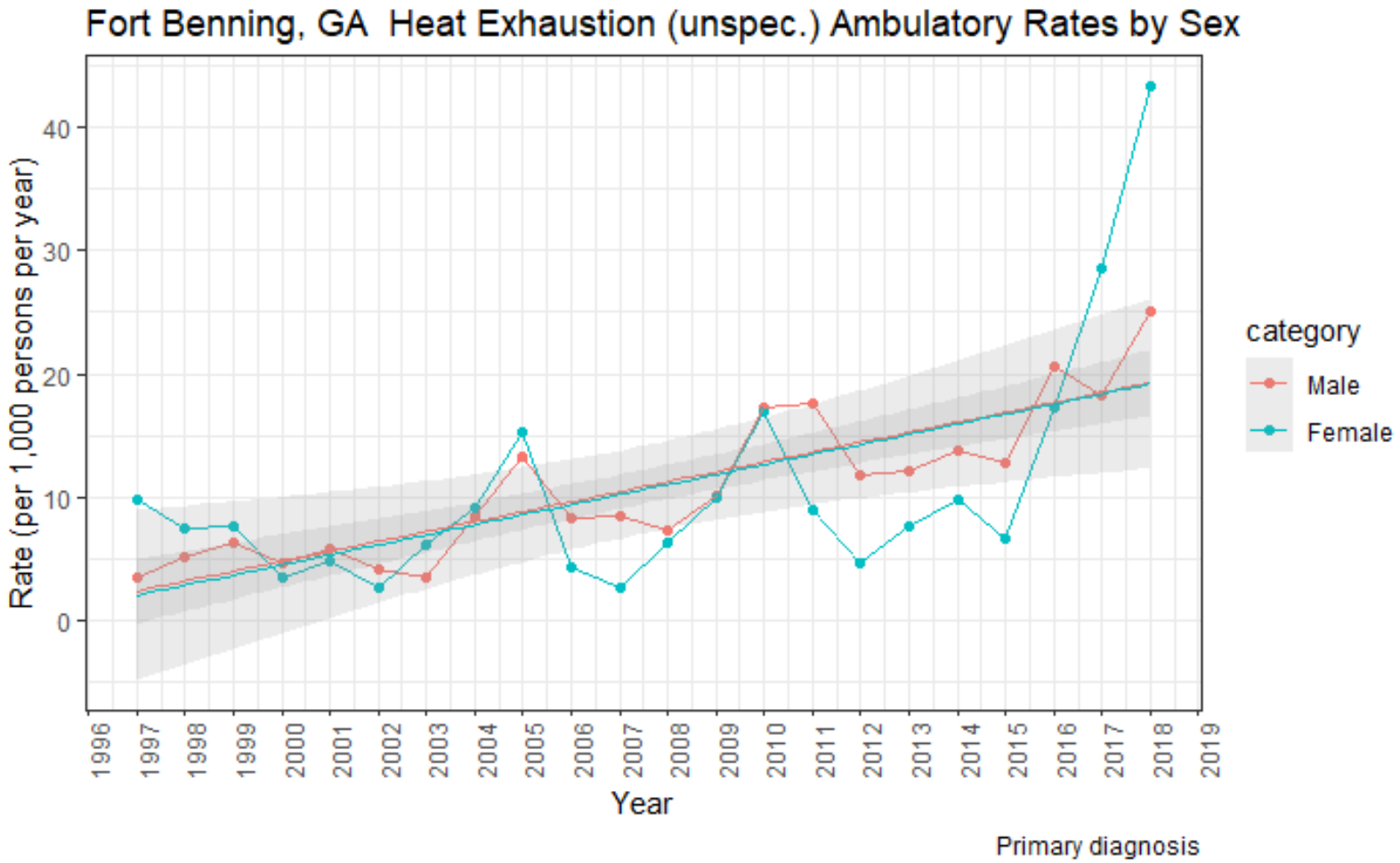


Hospitalizations

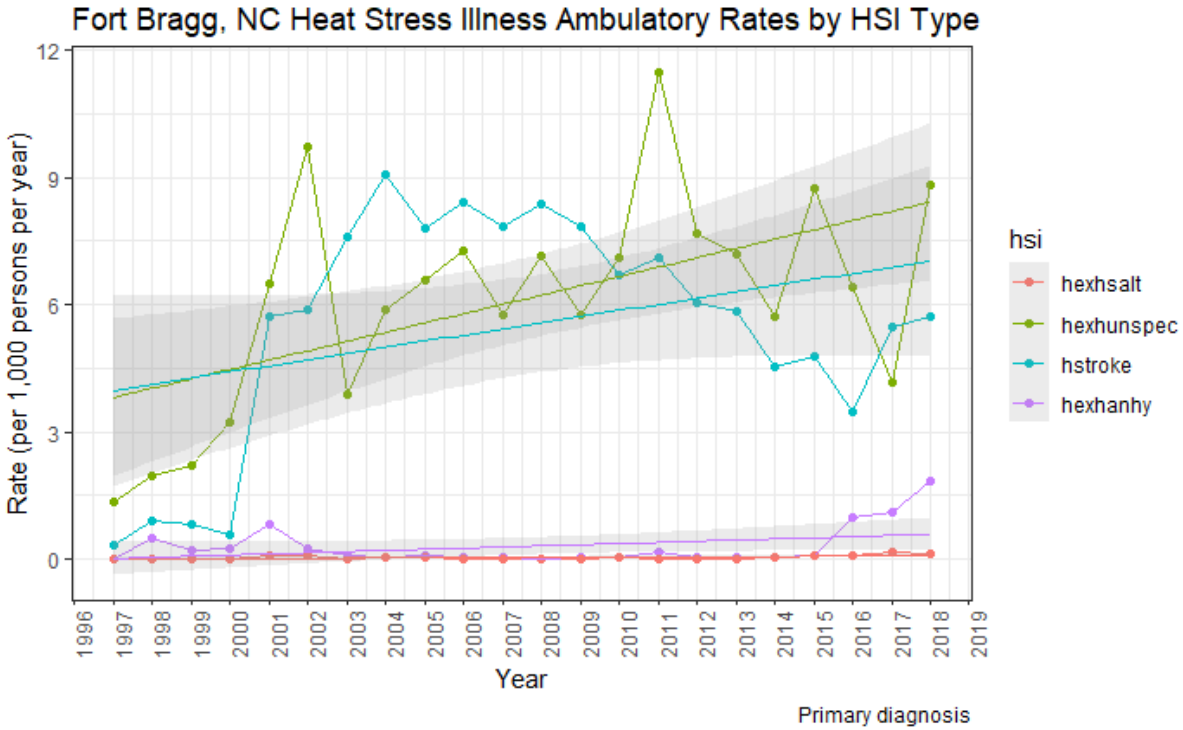
Fort Benning Hospitalization counts

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

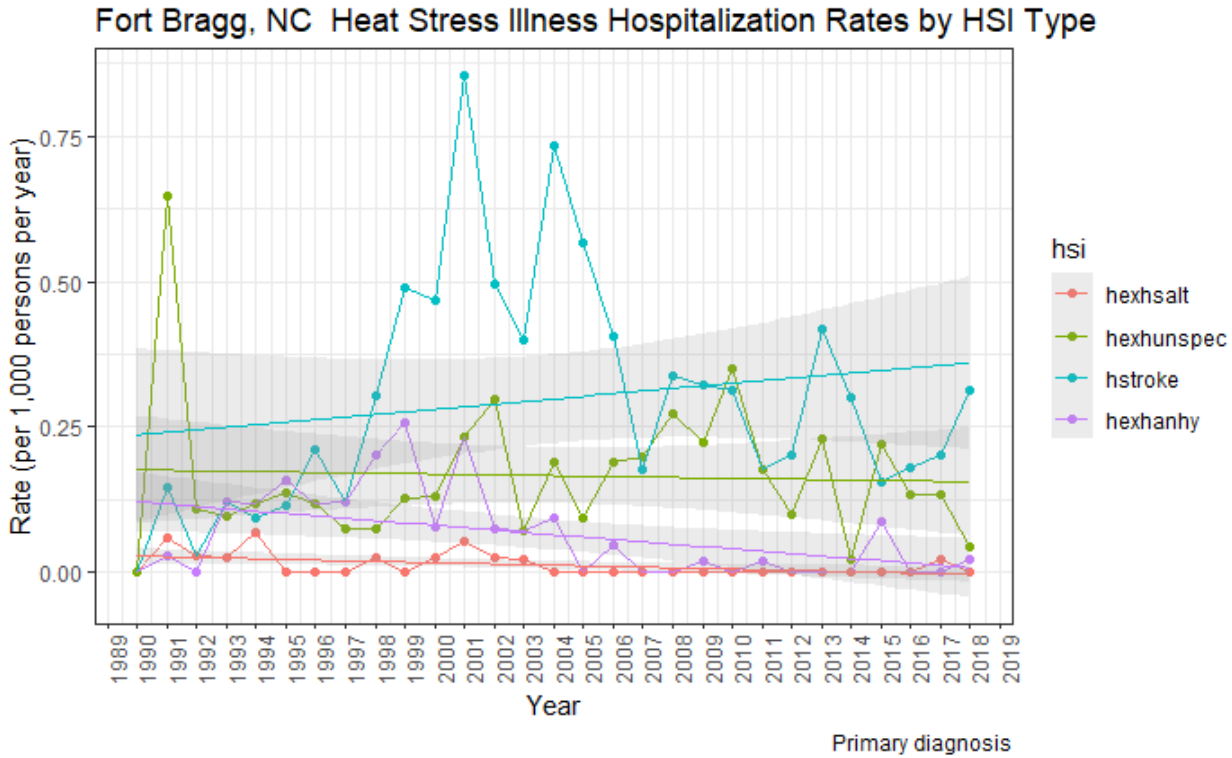
Fort Benning, GA – By Sex



Fort Bragg, NC



Ambulatory

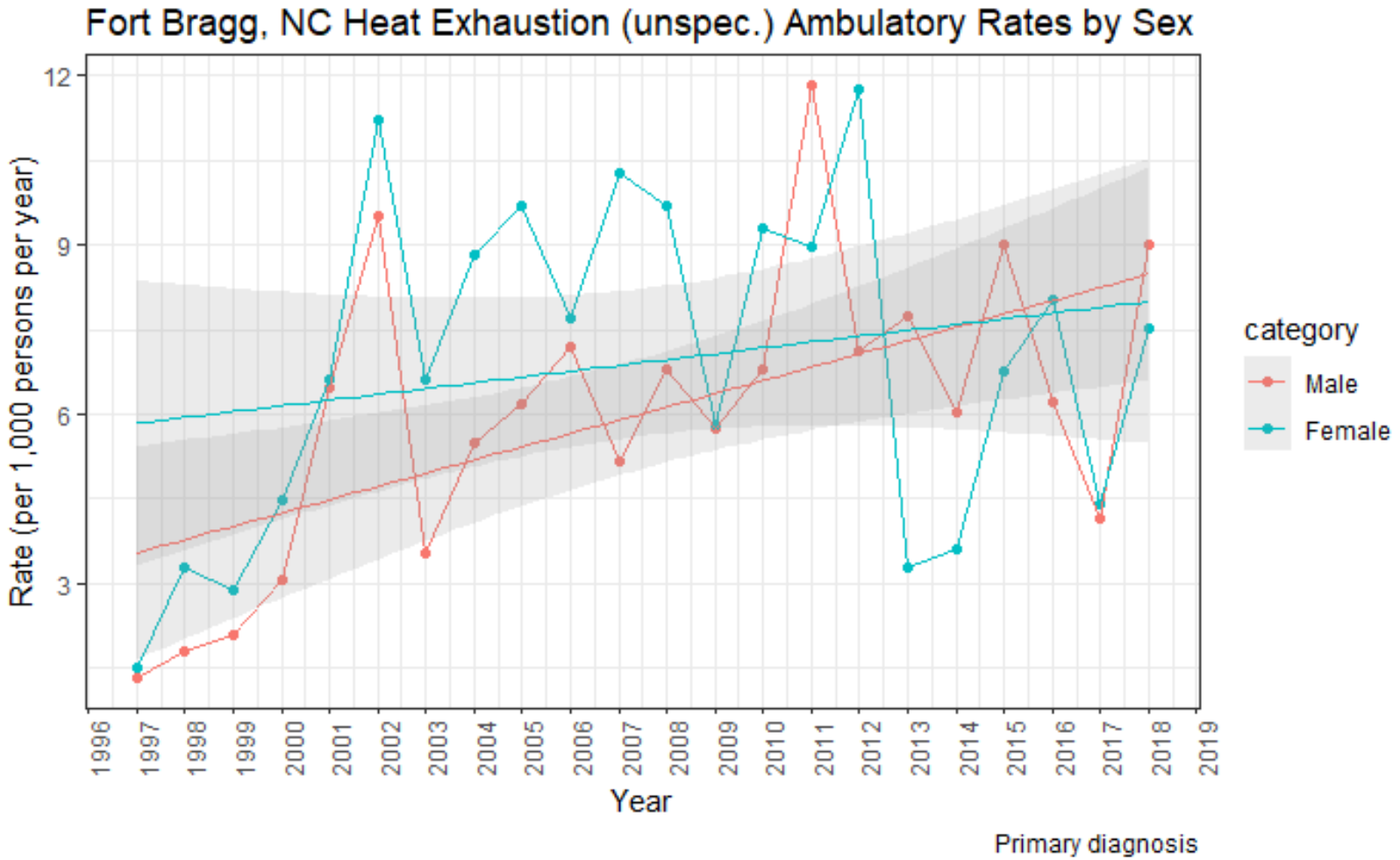


Hospitalizations

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