GRASS GIS 7:
A theoretical and practical course

Session 1 – GRASS GIS 7 and R-stats intro

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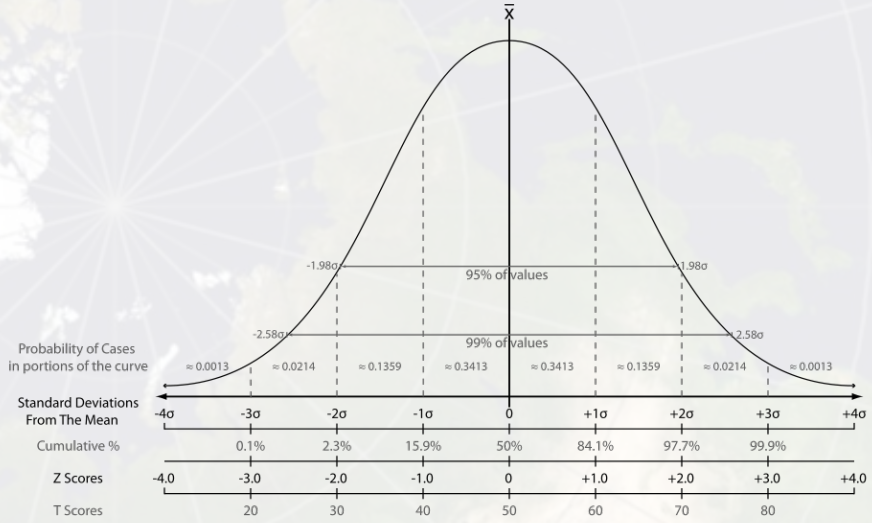

NINA 2016, Oslo, Norway

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Session Objectives

- GRASS GIS 7 and R-stats intro
- Examples:
  - Using R within a GRASS GIS session (incl RStudio)
  - Relationship elevation, latitude, distance from sea and temperature
    (this is a “circular” analysis, trying to reconstruct the input data from random sampling)

Exercise: GRASS GIS 7 and R statistics

Exercise: GRASS GIS 7 and R statistics

Using R within a GRASS GIS session

```
grass72
```

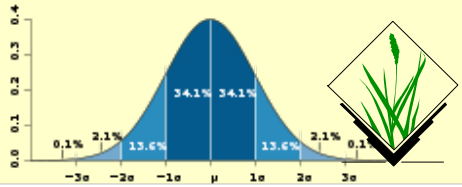
Set computational region to the map:

```
g.region raster=elev_state_500m -p
```

(Start of R – see next slide)

Wiki tutorial:

http://grass.osgeo.org/wiki/R_statistics → rgrass7 subpage



GRASS-R interface

Using R in a GRASS GIS session (North Carolina location)

R on Linux:

```
# Start R from GRASS session:
GRASS 7 > R
# … or: start rstudio from GRASS session:
GRASS 7 > rstudio
```

R on Mac OSX:

```
GRASS 7 > /Applications/RStudio.app/Contents/MacOS/RStudio
```

R in MS-Windows:

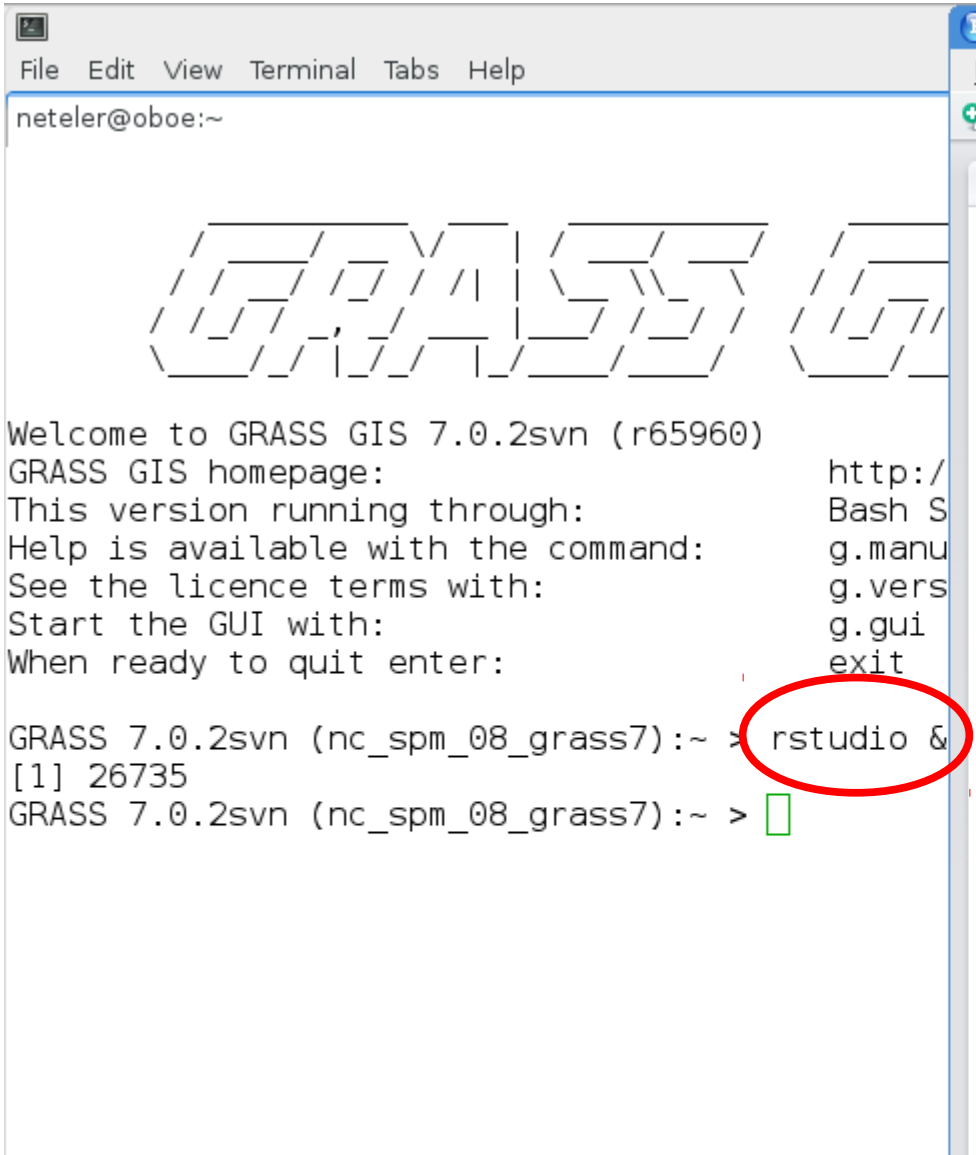
- use the “Explorer” to find the “RStudio.exe” in the R binaries folder
- **swipe** its **file icon** into the terminal of the running GRASS session, eg:

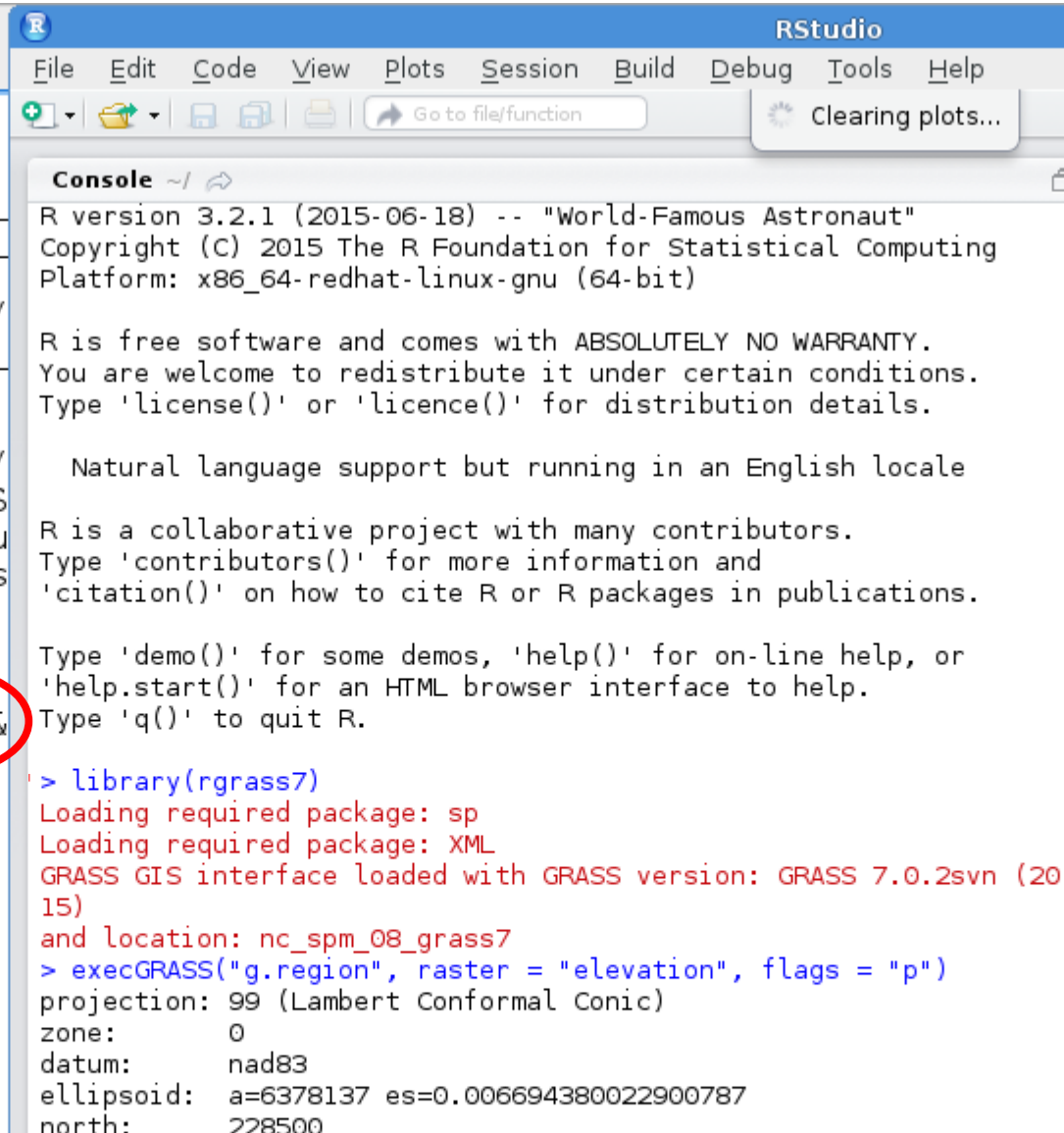
```
C:\Program Files\RStudio\bin\rstudio.exe
```

Exercise: GRASS GIS 7 and R statistics

Using R within a GRASS GIS session

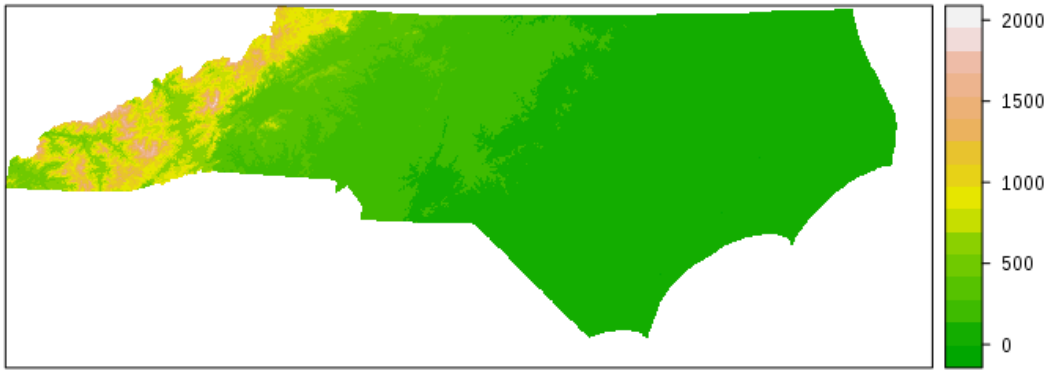
https://grasswiki.osgeo.org/wiki/R_statistics/rgrass7





Exercise: GRASS GIS 7 and R statistics

GRASS GIS and R statistical language (cont'd)

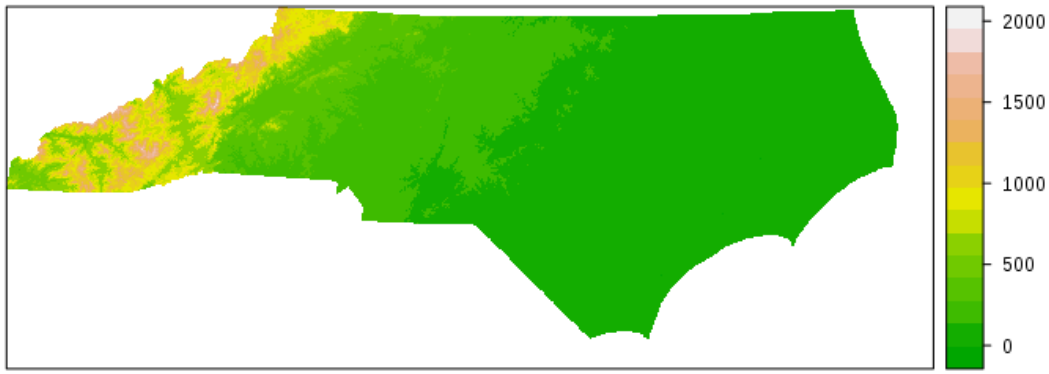



```
# get online help:
?readRAST

# get full help:
help.start()

# set computational region
execGRASS("g.region", parameters =
    list(raster = "elev_state_500m"), flags = "p")

# load GRASS DEM into R:
elev <- readRAST("elev_state_500m")

# show map metadata:
summary(elev)

# show map:
spplot(elev, col.regions=terrain.colors(20))
```

Exercise: GRASS GIS 7 and R statistics

GRASS GIS and R statistical language (cont'd)

```
# metadata
gmeta()
gisdbase    /home/neteler/grassdata
location    nc_spm_08_grass7
mapset      user1
rows        669
columns     1678
north       318500
south       -16000
west        124000
east        963000
nsres       500
ewres       500
projection  +proj=lcc +lat_1=36.16666666666666
+lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79
+x_0=609601.22 +y_0=0 +no_defs +a=6378137
+rf=298.257222101 +towgs84=0.000,0.000,0.000 +to_meter=1
```



Exercise: GRASS GIS 7 and R statistics

Using R within a GRASS GIS session (cont'ed)

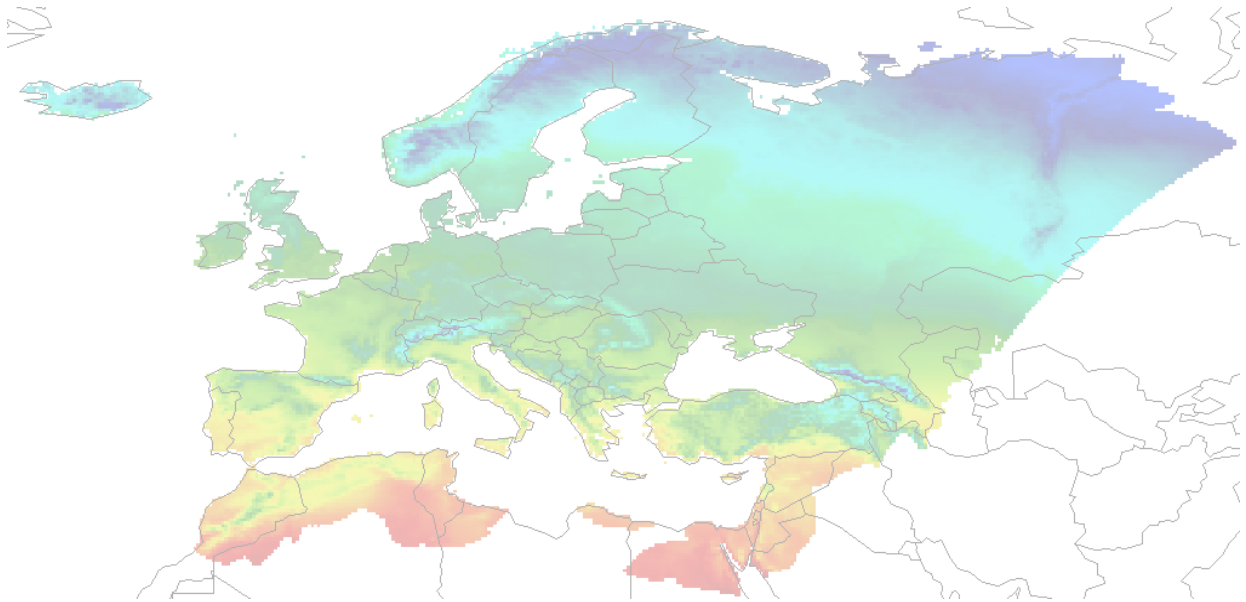
```
# list available vector maps:
> execGRASS("g.list", parameters = list(type = "vector"))
# loading a vector map into R space:
> myroads <- readVECT("roadsmajor")
Exporting 355 features [...]
It has 7 fields [...]

> str(myroads)
Formal class 'SpatialLinesDataFrame' [package "sp"] with 4 s
  ..@ data       :'data.frame':  355 obs. of  7 variables:
  .. ..$ cat       : int [1:355] 1 2 3 4 5 6 7 8 9 10 ...
  .. ..$ MAJORRDS_: num [1:355] 1 2 3 4 5 6 7 8 9 10 ...
  .. ..$ ROAD_NAME: Factor w/ 16 levels "I-40","I-440",..: 7
  .. ..$ MULTILANE: Factor w/ 2 levels "no","yes": 1 1 1 1 1
  .. ..$ PROPYEAR : int [1:355] 0 0 0 0 0 0 0 0 0 0 ...
  .. ..$ OBJECTID : int [1:355] 1 2 3 4 5 6 7 8 9 10 ...
  .. ..$ SHAPE_LEN: num [1:355] 4825 14393 3213 13392 7196 .
  ..@ lines      :List of 355
  .. ..$ :Formal class 'Lines' [package "sp"] with 2 slots
  .. .. .. ..@ Lines:List of 1
```

Exercise: GRASS GIS 7 and R statistics

Using R within a GRASS GIS session (cont'ed)

```
> summary(myroads)
Object of class SpatialLinesDataFrame
Coordinates:
       min      max
x 611136.5 676800.5
y 197465.3 257970.1
Is projected: TRUE
proj4string :
[+proj=lcc +lat_1=36.1666666666666 +lat_2=34.3333333333334
+lat_0=33.75 +lon_0=-79 +x_0=609601.22 +y_0=0 +datum=NAD83 +
+no_defs +ellps=GRS80 +towgs84=0,0,0]
Data attributes:
      cat           MAJORRDS_        ROAD_NAME    MULTILANE
 Min.   :  1.0   Min.   :  1.0   US-64  : 14   no  :115   Mi
 1st Qu.: 89.5   1st Qu.: 91.5   US-401 : 13   yes :154   1s
...

# end of session
> q()
```

Statistics with GRASS GIS and R: Analysing ECA&D climatic data



Overview

Course data download address:

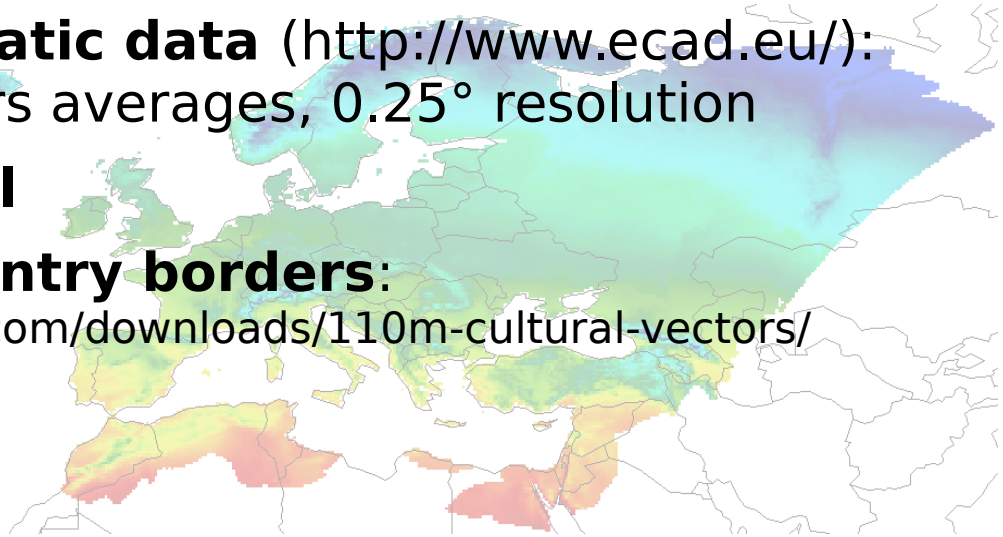
http://www.mundialis.de/workshops/nina2016/ecad5_geotiffs/

- `ecad5_geotiffs_LL.zip|tar.gz  5.1MB`

Get the package and save it on your computer.
Unpack the GeoTIFF files into your HOME/gis_data/

Content for exercises:

- Aggregated **ECA&D climatic data** (http://www.ecad.eu/):
  monthly data of 30 years averages, 0.25° resolution
- Related **elevation model**
- NaturalEarth Admin0 **country borders**:
  http://www.naturalearthdata.com/downloads/110m-cultural-vectors/



Overview

Aggregated daily ECA&D data in detail:

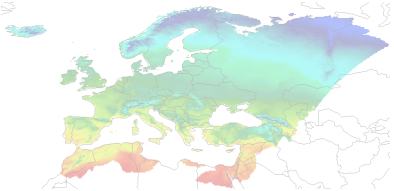
elevation model (DEM):
ecad5_geotiffs_LL/elev_0.25deg_reg_v6.0.tif

12 maps of monthly sums over 30 years
ecad5_geotiffs_LL/precip_1951_1980_monthly_sums.tif
ecad5_geotiffs_LL/precip_1981_2010_monthly_sums.tif

average of annual sums over 30 years
ecad5_geotiffs_LL/precip_1981_2010_avg.tif

12 maps of monthly tmean averaged over 30 years
ecad5_geotiffs_LL/tmean_1951_1980_monthly_avgs.tif
ecad5_geotiffs_LL/tmean_1981_2010_monthly_avgs.tif

Solar angles calculated from elev_0.25deg_reg_v6.0.tif in GRASS GIS:
ecad5_geotiffs_LL/ecad_solarangle_elev.tif

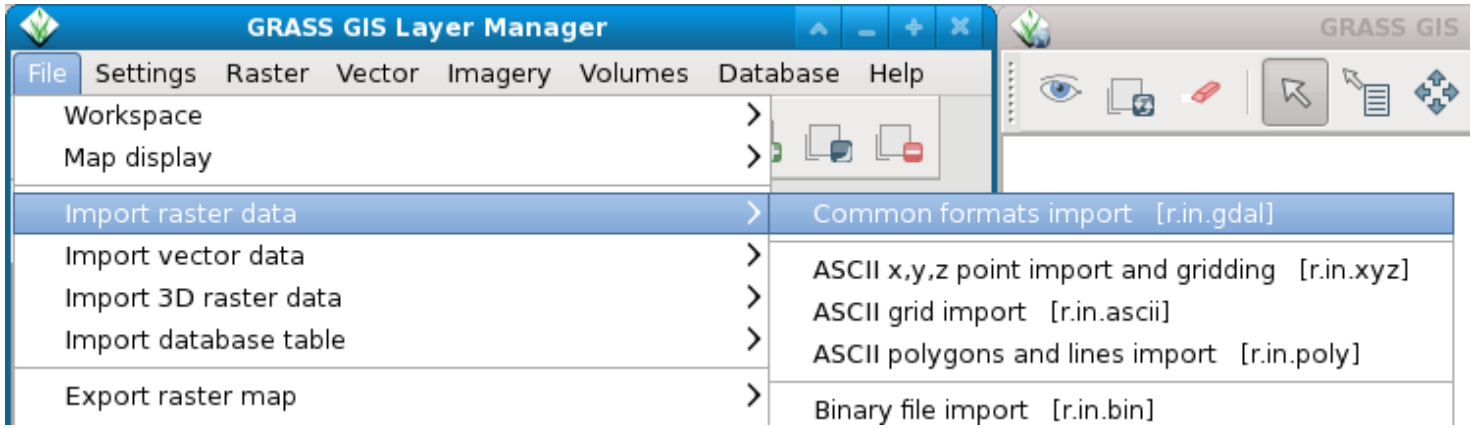


Exercise – GRASS GIS 7 startup with ECA&D data

Exercise – Importing data

Import the elevation map in GeoTIFF format

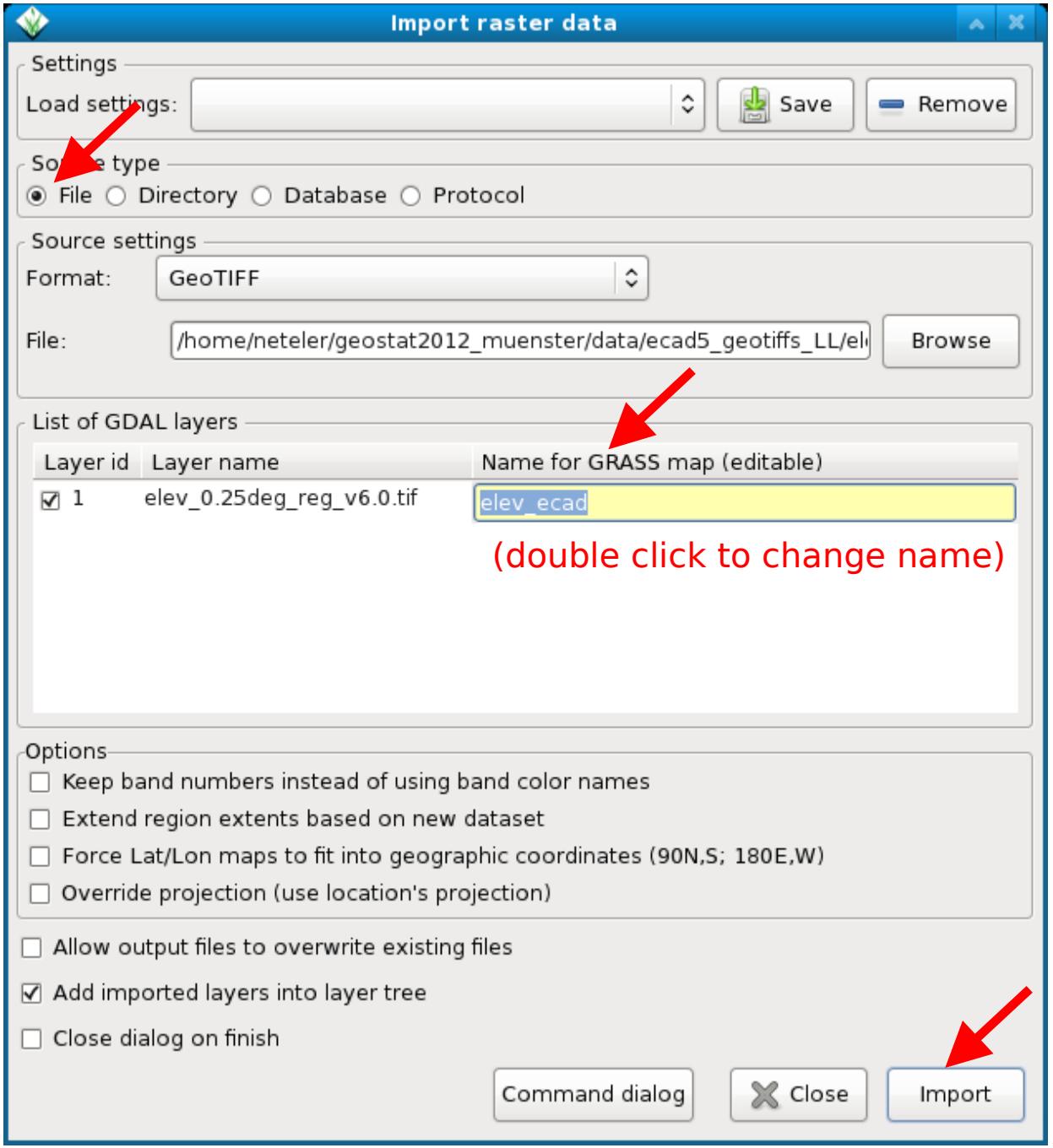
The ECA&D elevation map is the GeoTIFF file
“elev_0.25deg_reg_v6.0.tif”



Exercise – Importing data

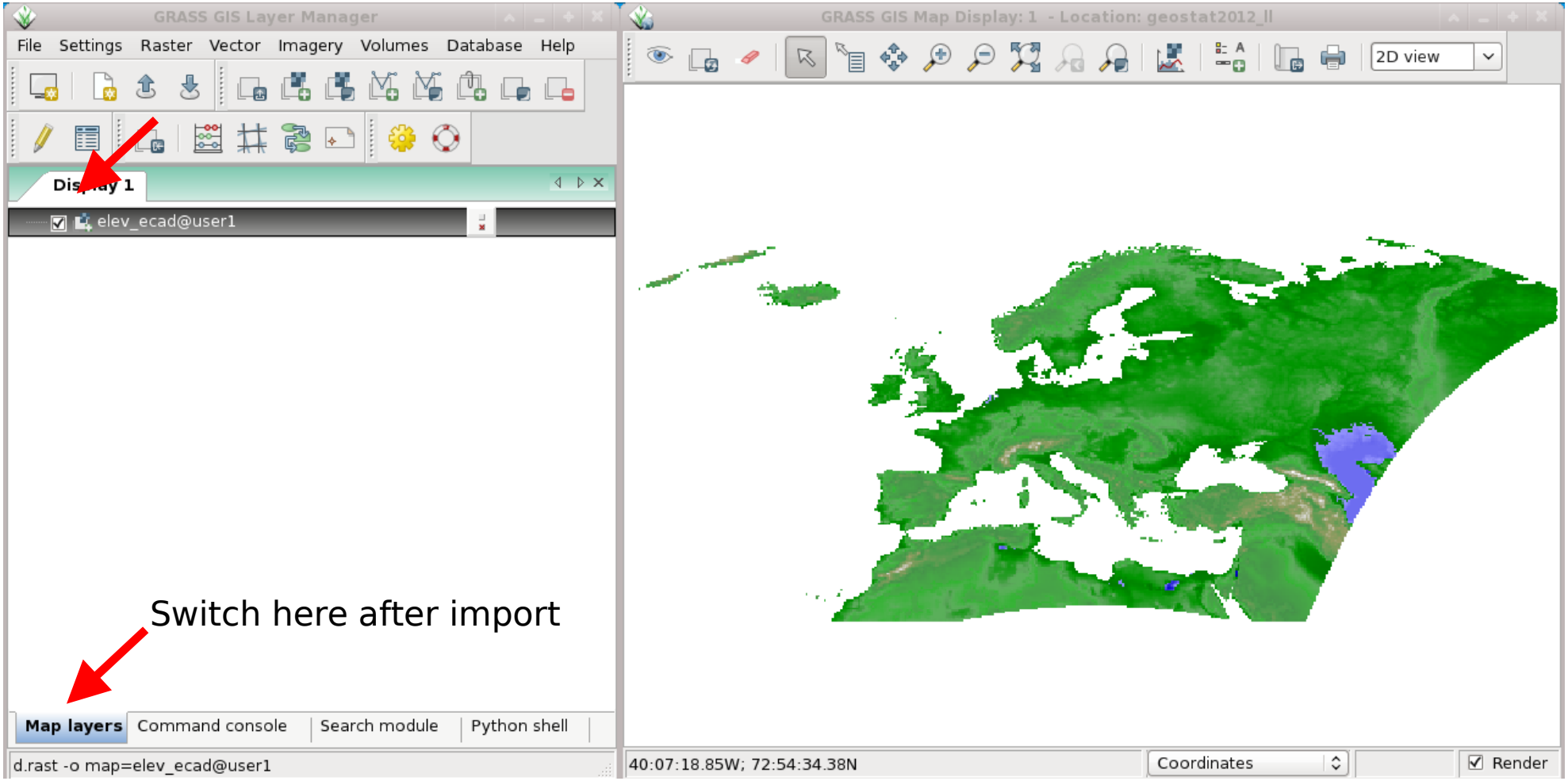
Import elevation map dialog

We rename to “elev_ecad”

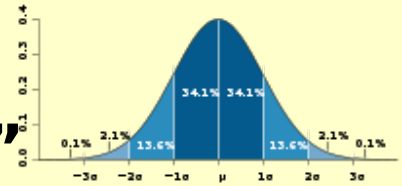


Exercise – GRASS startup and first steps

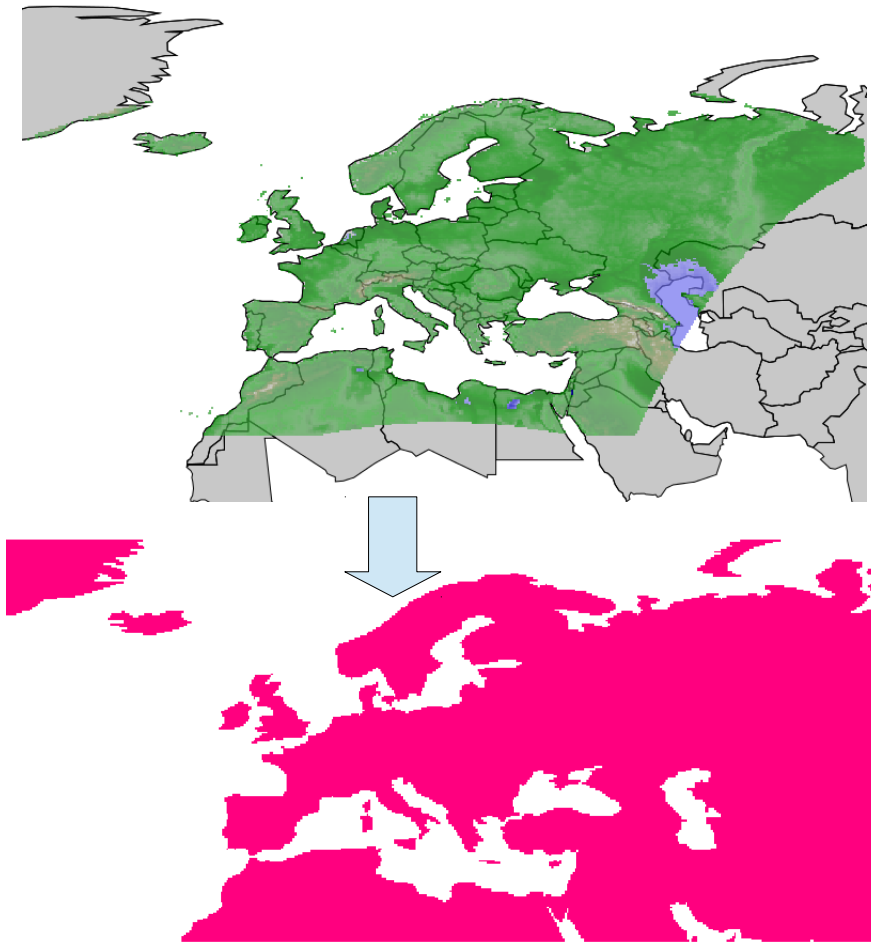
Click on the checkbox in layer manager to show the imported map.
After import, apply the “terrain”, “elevation” or “srtm” color table.

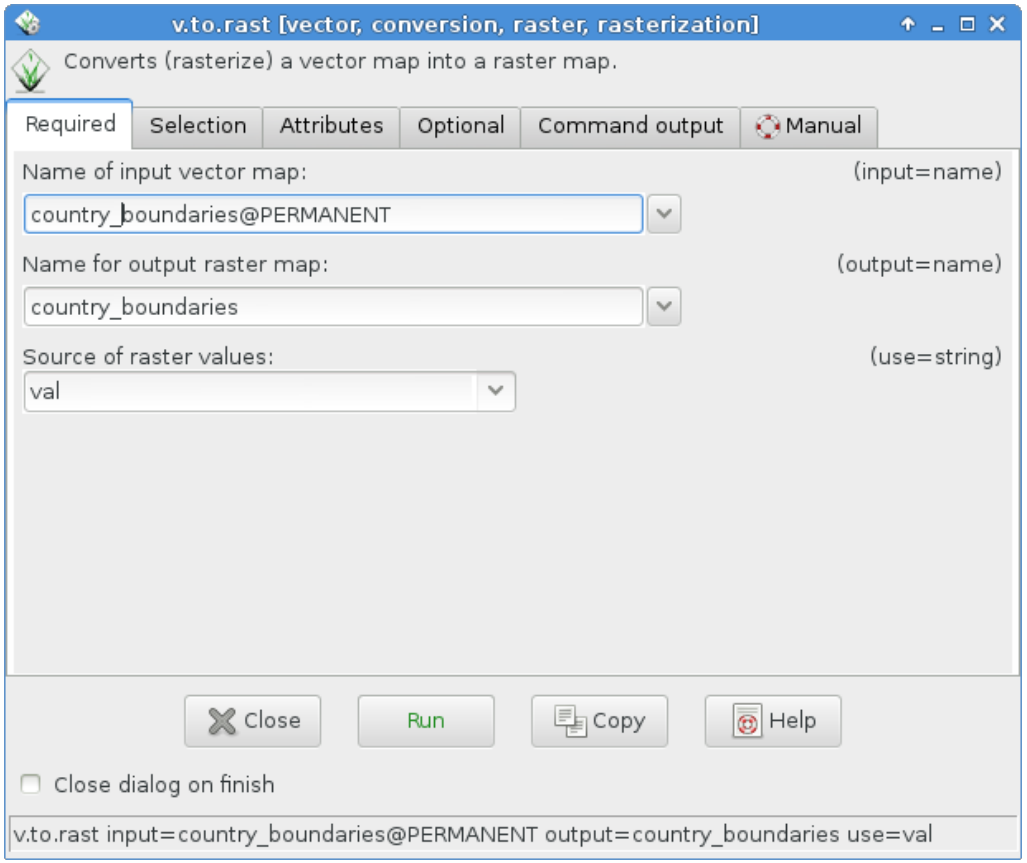


Analysing the relationship between “distance from sea” and “temperature”



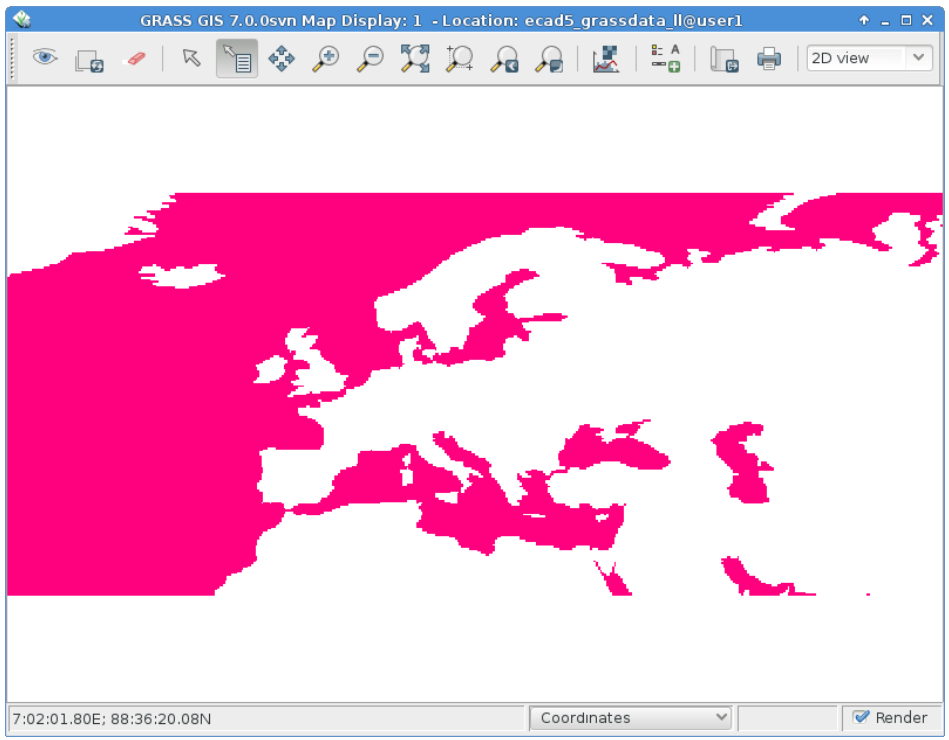

```
# As usual, let's be picky about the computational region:
g.region raster=elev_ecad -p

# generate a “sea” map first (you may use the country borders):
v.to.rast in=country_boundaries output=country_boundaries \
          use=val value=1
```

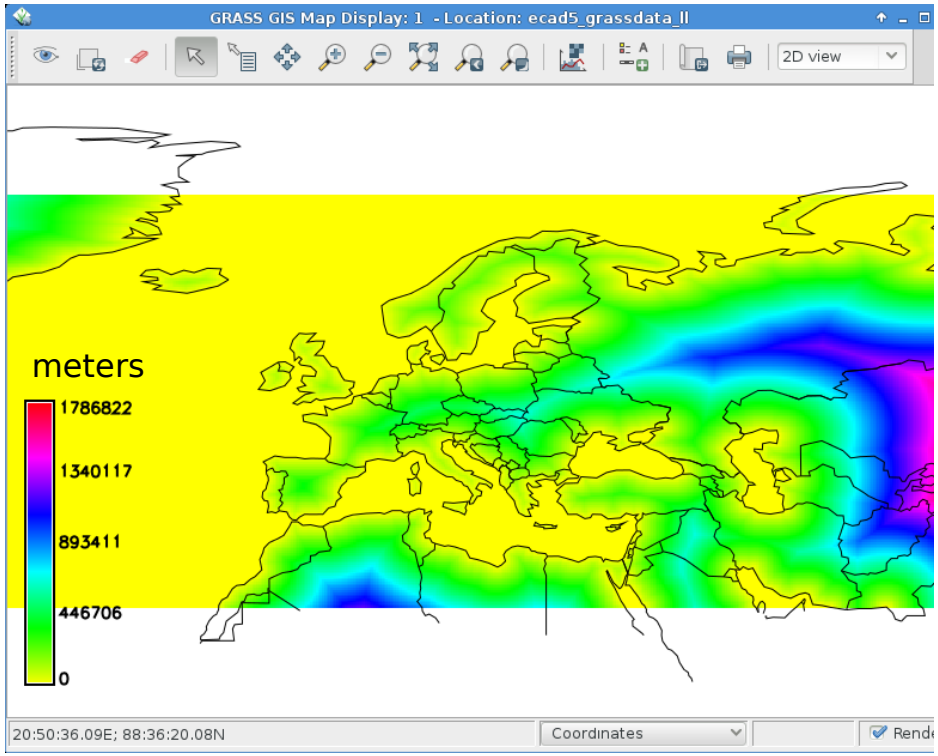




Analysing the relationship between “distance from sea” and “temperature”


```
# invert “land” map to “sea” map to get “distance from sea”:
r.mapcalc "sea = if(isnull(country_boundaries), 1, null() )"

# calculate geodesic distances in [m] (since we are in LatLong)
# -m   Output distances in [m] instead of map units [deg. here]
# insert as one line:
r.grow.distance -m input=sea distance=dist_from_sea \
                metric=geodesic
```





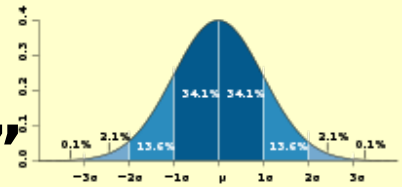
Analysing the relationship between “distance from sea” and “temperature”

Now we calculate overall average of T_mean

```
# see list of maps and decide the pattern for the names:
g.list raster

# test the pattern selection
g.list raster pattern="tmean.1981_2010.*.avg"

# test the pattern selection with separator:
g.list raster pattern="tmean.1981_2010.*.avg" sep=","

# aggregate this time series
g.list raster pattern="tmean.1981_2010.*.avg" \
        output=list_tmean.csv
r.series file=list_tmean.csv \
     output=tmean.1981_2010.avg method=average

# check extended univariate statistics
r.univar -e tmean.1981_2010.avg

#... validate: are min/max/mean values reasonable?
```

Cont.

Analysing the relationship between “distance from sea” and “temperature”



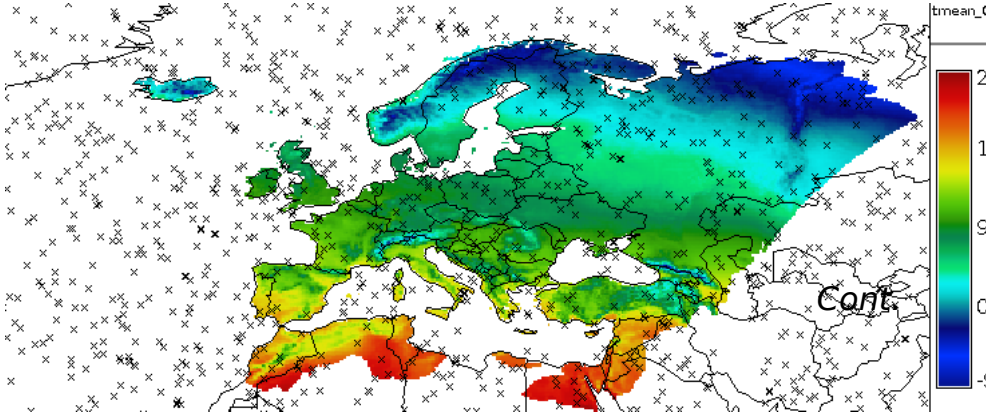

```
# random sampling of 1000 "meteo-stations": generate points.
# we sample many due to “stations” falling into the sea = no-data:
v.random output=t_mean_europe_random1000 n=1000

# assign attributes to these random vector points
v.db.addtable t_mean_europe_random1000 \
     columns="t_mean double precision, dist_sea double precision"

# was the table created?
v.info -c t_mean_europe_random1000
v.db.select t_mean_europe_random1000
```

→ we now have the points with a yet unpopulated attribute table column.

Note: we use v.random here to illustrate the use of SQL – there is also r.random which extracts vector values right away

Now display random points map

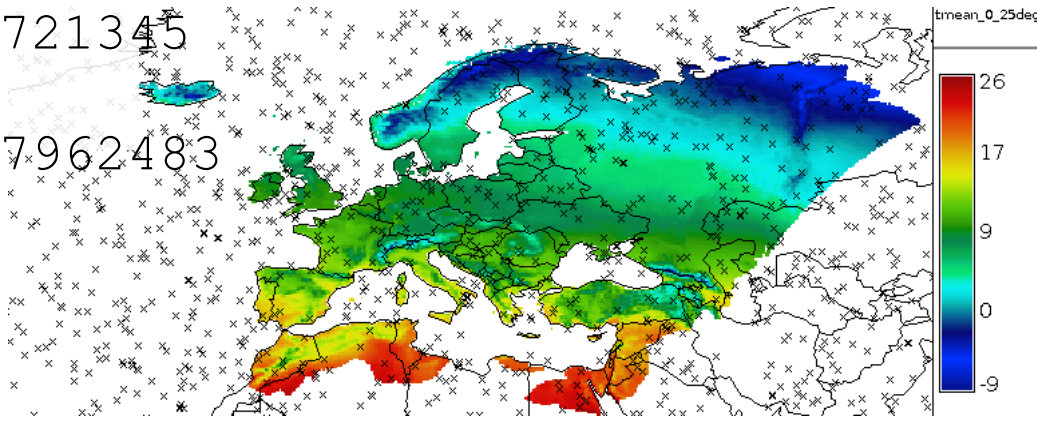
note: those virtual “stations” in the sea we'll drop later



Analysing the relationship between “distance from sea” and “temperature”

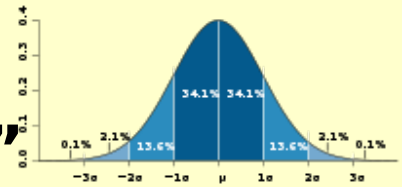
Now we populate the attribute table by querying the raster maps at the positions of the random vector points:

```
# fetch attrib. values from raster maps:
#       distance from sea and t_mean
v.what.rast map=t_mean_europe_random1000 \
          raster=tmean.1981_2010.avg column=t_mean
v.what.rast map=t_mean_europe_random1000 \
           raster=dist_from_sea column=dist_sea

# verify
v.db.select t_mean_europe_random1000 separator=comma
 cat,t_mean,dist_sea
 1,,0
 2,,836479.019992906
 3,14.420371055603,179800.318721345
 4,,0
 5,1.48298296425492,91898.5987962483
 ...
```



Cont.

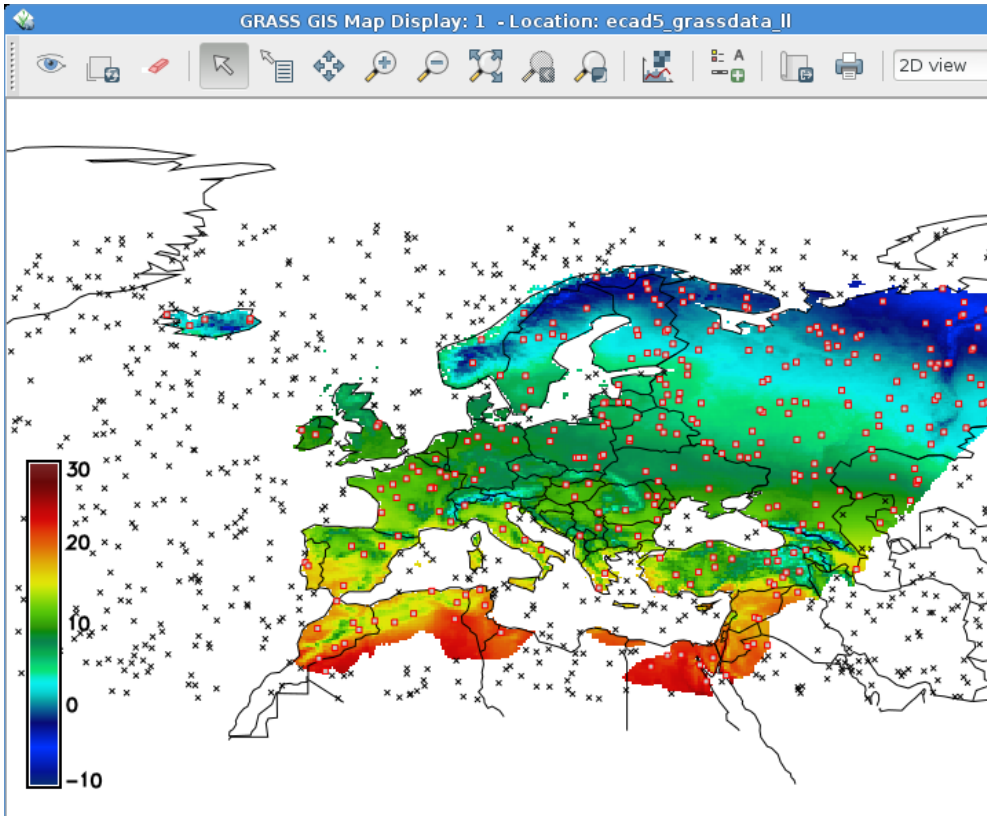
Analysing the relationship between “distance from sea” and “temperature”



Now we have the prepared vector map with attributes

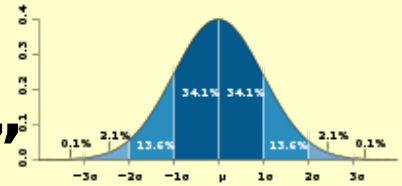
```
# Now we drop stations positioned in the sea, as well as
# no data stations using a SQL where statement (approx.
# 1/3 of the point will remain):
v.extract input=t_mean_europe_random1000 \
    where="dist_sea > 0.0 AND t_mean NOT NULL" \
    output=t_mean_europe_meteo
```

```
# show 'em ( or use wxGUI)
d.vect t_mean_europe_meteo \
    color=red \
    icon=basic/box
d.vect country_boundaries \
    type=boundary
```

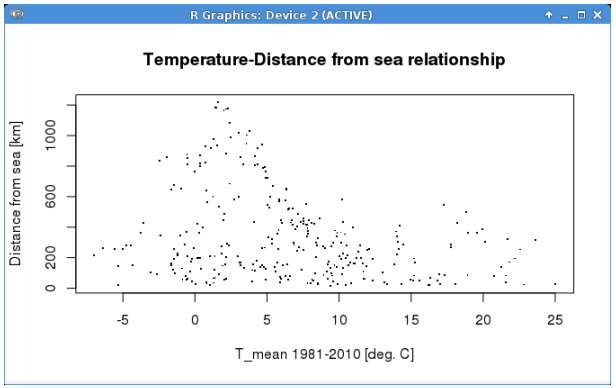


Cont.

Analysing the relationship between "distance from sea" and "temperature"

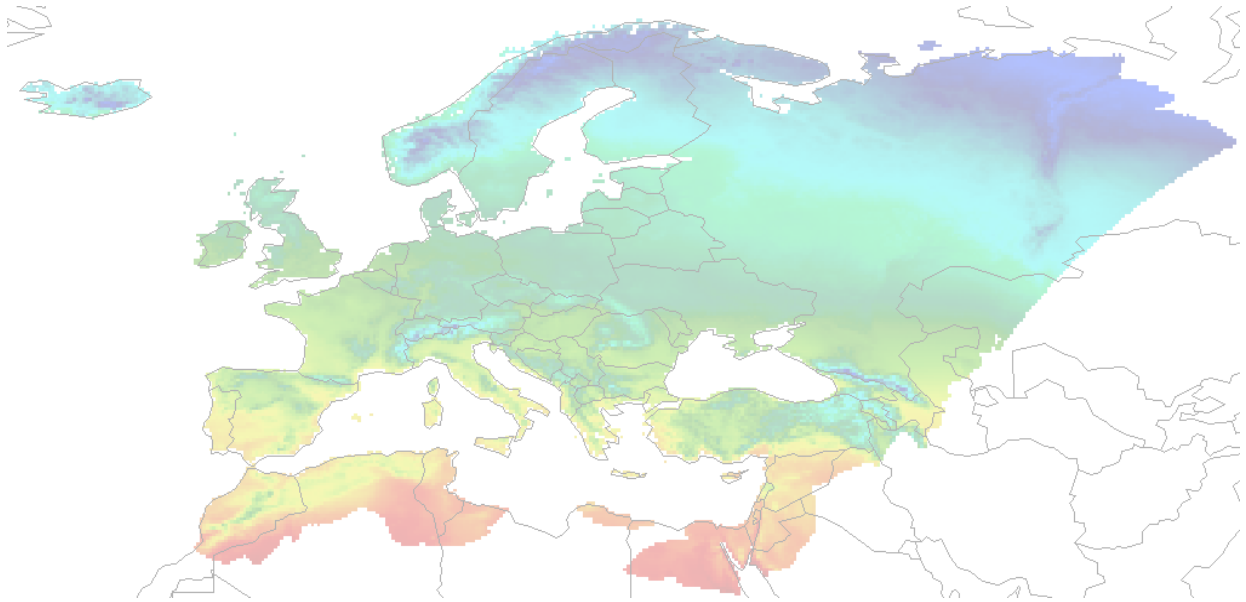


```
# Now we analyse these vector point data in R
R
library(rgrass7)
mydata <- readVECT("t_mean_europe_meteo")
summary(mydata)

# show as points map; histogram plot of T_mean
spplot(mydata)
hist(mydata$t_mean)

# rescale dist_from_sea to km
mydata$dist_sea <- mydata$dist_sea/1000.0
summary(mydata)

# scatterplot
plot (mydata$dist_sea ~ mydata$t_mean, cex=2, pch=".",
      xlab="T_mean 1981-2010 [deg. C]",
      ylab="Distance from sea [km]",
      main="Temperature-Distance from sea relationship")
```

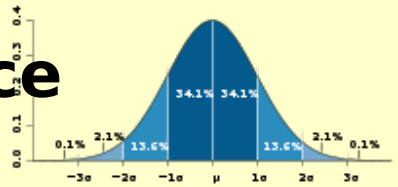


...well, not much to be seen: Across climatic zones we don't find a simple relationship! So we try harder now...

Linear models with GRASS GIS and R



Relationship elevation, latitude, distance from sea and temperature

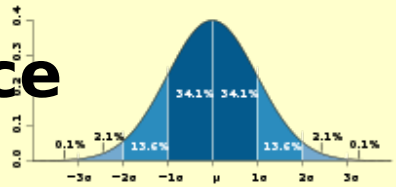


Next round: we introduce more variables (and `q()` from R for this)

```
r.mapcalc "latitude = y()"

# add new column and values
v.db.addcolumn t_mean_europe_meteo \
    columns="latitude double precision, \
     elevation double precision"
v.what.rast map=t_mean_europe_meteo \
    raster=latitude column=latitude
v.what.rast map=t_mean_europe_meteo \
    raster=elev_ecad column=elevation

# update distance from sea to km in database
v.db.update t_mean_europe_meteo column=dist_sea \
        qcolumn="dist_sea / 1000.0"

# verify
v.db.select t_mean_europe_meteo
cat|t_mean|dist_sea|latitude|elevation
1|3.978974784413 97|46.602624554631 1|63.125|355.108
3|10.17351547504 46|297.07057880940 6|39.125|1100.738
9|4.732688109 08|790.0353811265 79|53.125|219.3317
...
```

Cont.

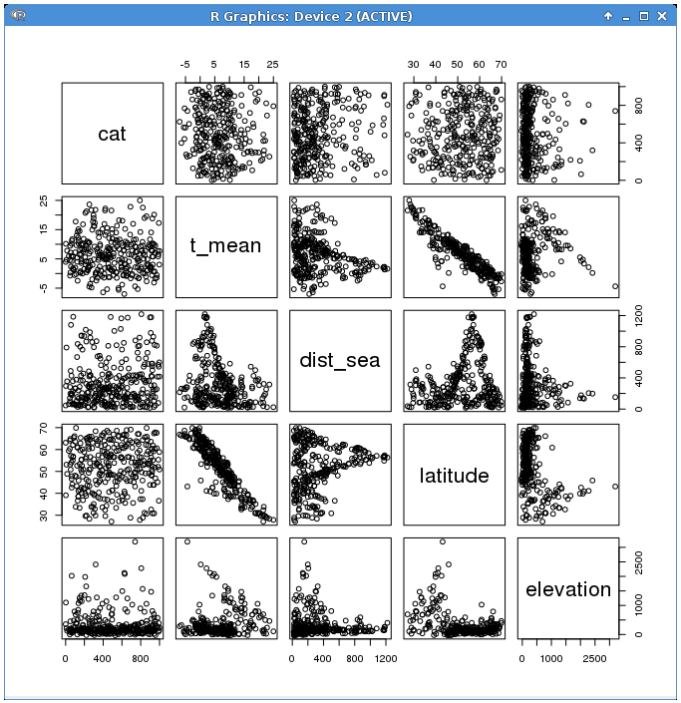
Relationship elevation, latitude, distance from sea and temperature



Restart R in your GRASS GIS session

```
R
library(rgrass7)
mydata <- readVECT("t_mean_europe_meteo")
summary(mydata)

# get rid of nodata
summary(mydata)
mydata <- mydata[!is.na(mydata$t_mean),]

# plot the variables
# against each other
plot(mydata@data)
```

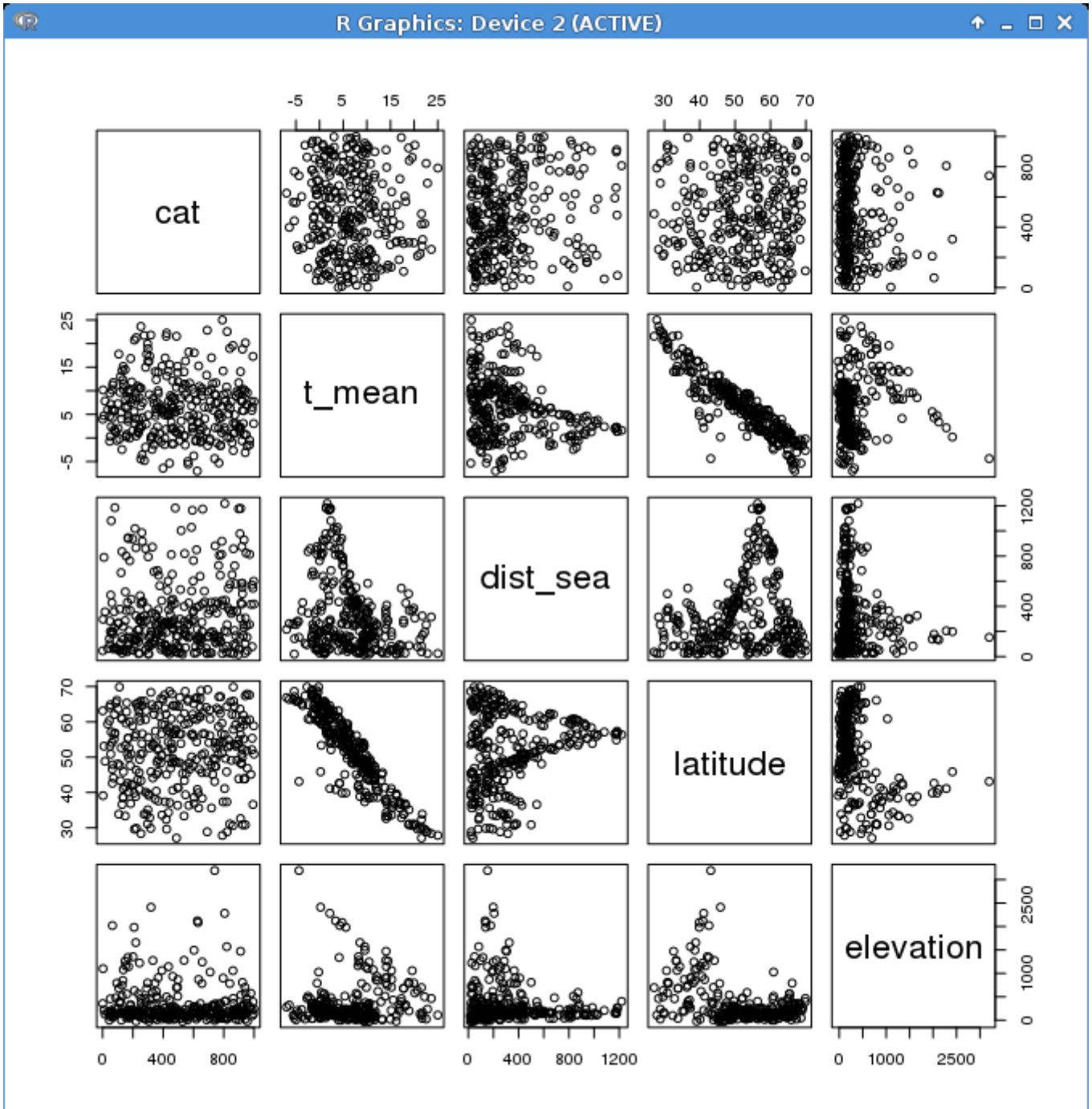
Hints: there is also an extra raster map available: "ecad_solarangle_elev.tif" in order to add yet another Variable, calculated with r.sunhours in GRASS GIS



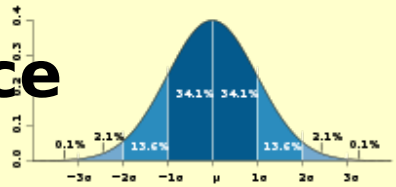
See next page for larger figure

Cont.

Relationship elevation, latitude, distance from sea and temperature



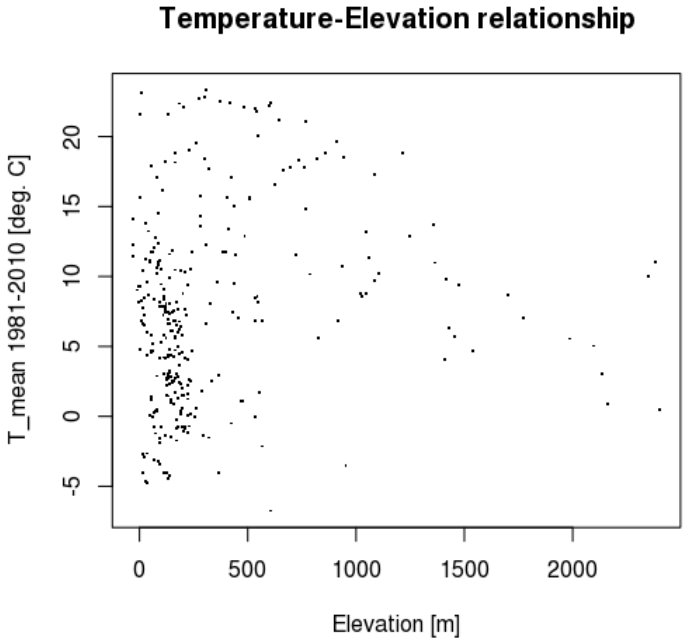
Relationship elevation, latitude, distance from sea and temperature

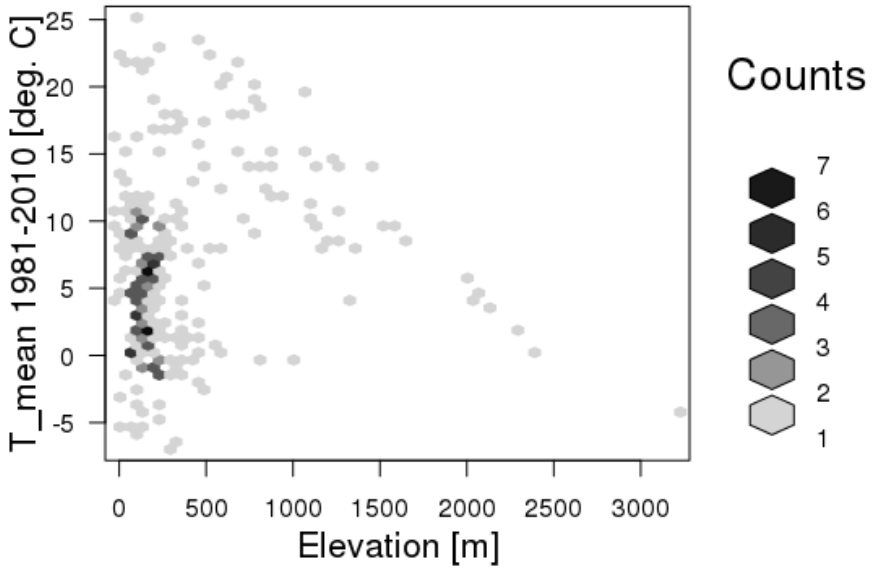



```
# scatterplot T_mean vs Elevation
plot (t_mean ~ elevation, mydata, cex=2, pch=".",
      xlab="Elevation [m]", ylab="T_mean 1981-2010 [deg. C]",
      main="Temperature-Elevation relationship")
```

Hint – Having too many points? Try “hexagon binning”

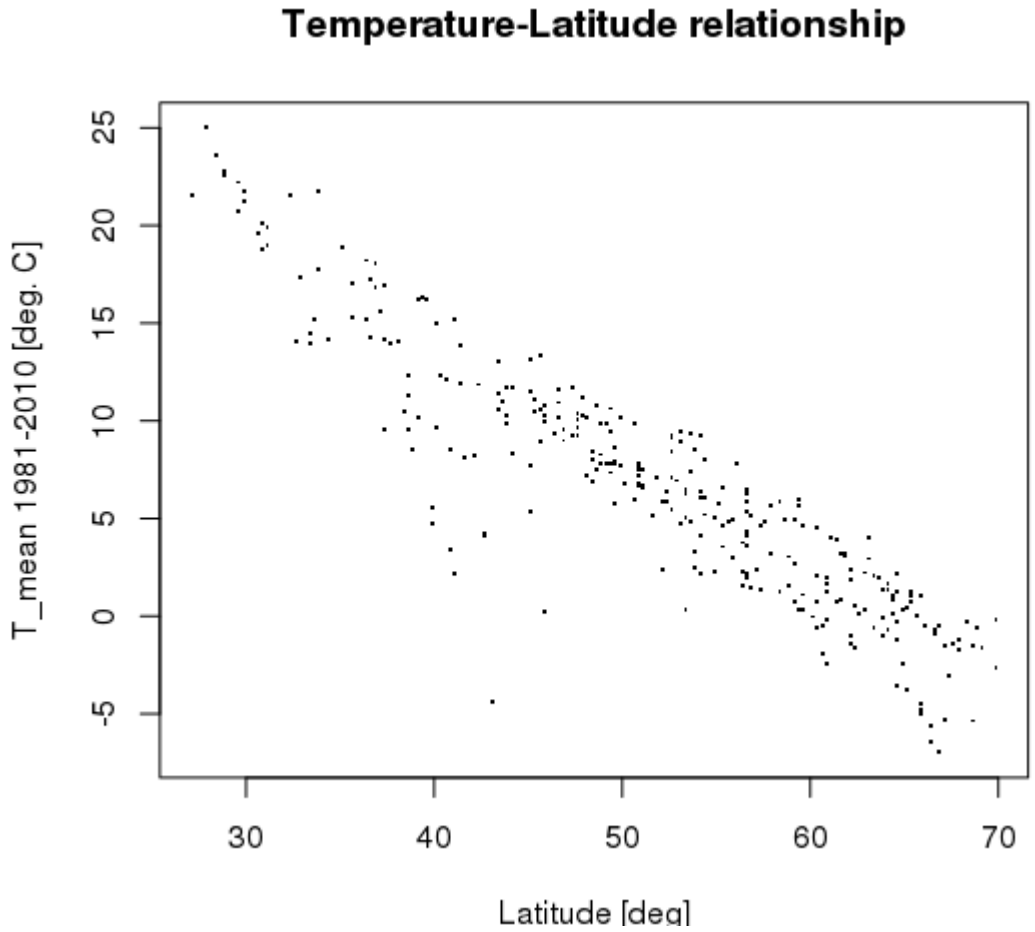
```
# requires: install.packages("hexbin")
library(hexbin)
hbin <- hexbin(mydata$elevation, mydata$t_mean, xbins = 50,
  xlab="Elevation [m]", ylab="T_mean 1981-2010 [deg. C]")
plot(hbin)
```



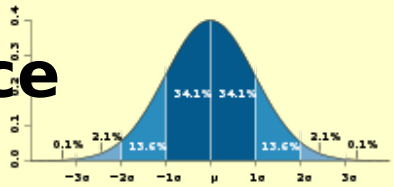


Relationship elevation, latitude, distance from sea and temperature

```
# scatterplot T_mean vs Latitude
plot (t_mean ~ latitude, mydata, cex=2, pch=".",
      xlab="Latitude [deg]", ylab="T_mean 1981-2010 [deg. C]",
      main="Temperature-Latitude relationship")
```



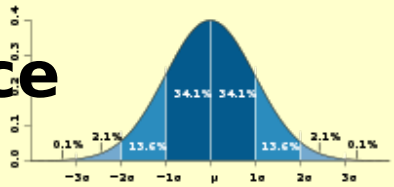
Relationship elevation, latitude, distance from sea and temperature




```
# Linear model T_mean vs Latitude
linmodel <- lm(t_mean ~ latitude, mydata)
abline(linmodel, col="red")
summary(linmodel)

Residuals:
     Min       1Q   Median       3Q      Max
-15.7127  -1.1581   0.3328   1.6983   5.2907

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 34.98965    0.74636   46.88   <2e-16 ***
latitude    -0.54793    0.01408  -38.91   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.602 on 304 degrees of freedom
Multiple R-squared:  0.8328,Adjusted R-squared:  0.8322
F-statistic:  1514 on 1 and 304 DF,  p-value: < 2.2e-16
```

Due to random sampling
Values may slightly differ

Relationship elevation, latitude, distance from sea and temperature

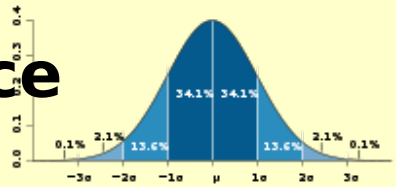


Perform the same calculation in GRASS GIS

```
# (use CTRL-Z in R to suspend ("park") it,
# and "fg" command to get back into the R session)

r.regression.line map1=latitude \
          map2=tmean.1981_2010.avg -g
a=36.007617
b=-0.565162
R=-0.930083
N=30311
F=194291.514322
meanX=51.388518
sdX=10.863195
meanY=6.964766
sdY=6.600992
```

BUT:
... note that here ALL raster points are considered here, not only the random vector points

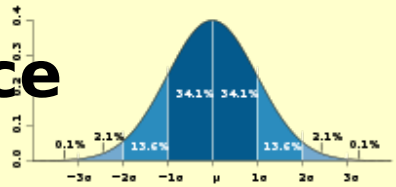
Relationship elevation, latitude, distance from sea and temperature



Creating a multivariate linear model:

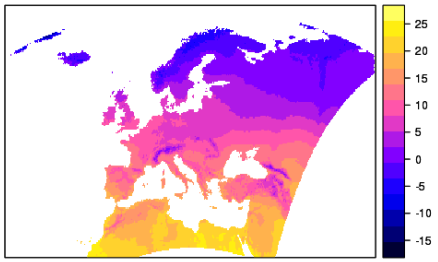
```
# y = b0 + b1x1 + b2x2 + ... + bnxn + ϵ
#
# Linear model T_mean vs Elevation + Latitude + dist_from_sea:
linmodel <- lm(t_mean ~ elevation + latitude + dist_sea, mydata)

summary(linmodel)
 Residuals:
     Min       1Q   Median       3Q      Max
 -4.9705 -0.8431   0.3034   0.9686   3.6243
 Coefficients:
               Estimate Std. Error t value Pr(>|t|)
 (Intercept) 41.3338066  0.5212465   79.30   <2e-16 ***
 elevation   -0.0048608  0.0002197  -22.13   <2e-16 ***
 latitude    -0.6166385  0.0092093  -66.96   <2e-16 ***
 dist_sea    -0.0034204  0.0003131  -10.93   <2e-16 ***
 ---
 Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
 Residual standard error: 1.532 on 301 degrees of freedom
   (1 observation deleted due to missingness)
 Multiple R-squared:  0.9422,   Adjusted R-squared:  0.9416
 F-statistic:  1635 on 3 and 301 DF,  p-value: < 2.2e-16


coefficients(linmodel)
  (Intercept)     elevation      latitude      dist_sea
 41.333806589 -0.004860809 -0.616638492 -0.003420416
```

Relationship elevation, latitude, distance from sea and temperature

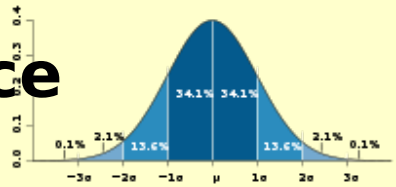


Creating "t_mean_model" the map “the R way…”

```
mymaps <- readRAST(c("elev_ecad", "latitude",
  "dist_from_sea"))
summary(mymaps)
# rename to match names of linear model
names(mymaps) <- c("elevation", "latitude", "dist_sea")
summary(mymaps)
# look at one of the maps
spplot(mymaps, "elevation")

# convert m to km
mymaps$dist_sea <- mymaps$dist_sea / 1000.0

# predict T_mean from linear model
mymaps$t_mean_model <- predict(linmodel, newdata=mymaps)
summary(mymaps)
str(mymaps@data)
spplot(mymaps, "t_mean_model")

# write out to GRASS:
writeRAST(mymaps, "t_mean_model_R", zcol="t_mean_model")
```



Relationship elevation, latitude, distance from sea and temperature



Creating the "t_mean_model" map the GRASS way…
(interesting approach when dealing with HUGE datasets!)

Linear model
$$y = b_0 + b_1x_1 + b_2x_2 + ... + b_nx_n + \epsilon$$
General formula in GRASS GIS:
`r.mapcalc "t_mean_model = $b0 + $b1 * var1 + $b2 * var2`

we copy-paste the values from the linear model created before
as **shell variables** into the terminal (no white space allowed):

```
# Intercept
b0=41.3338066
# elev_ecad
b1=-0.0048608
# latitude
b2=-0.6166385
# dist_from_sea
b3=-0.0034204
```

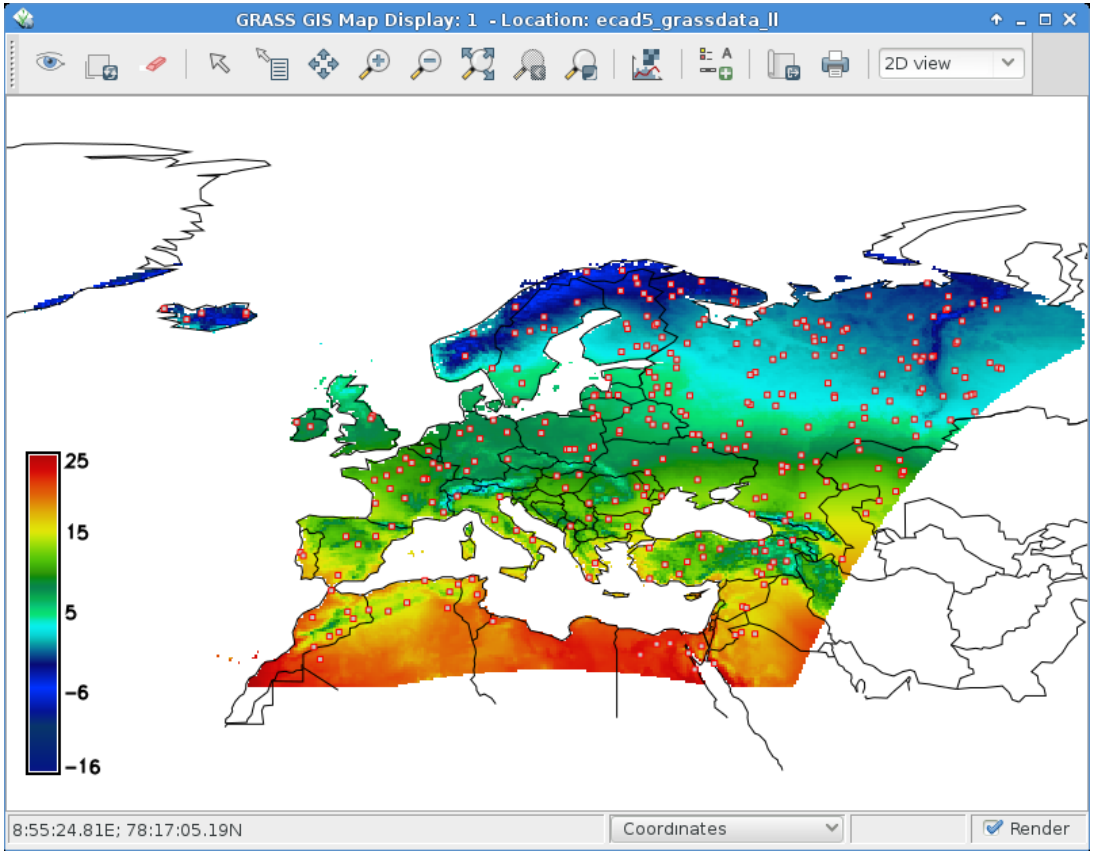
Hint: write this into a file and “source” it (. file) into GRASS session

Relationship elevation, latitude, distance from sea and temperature

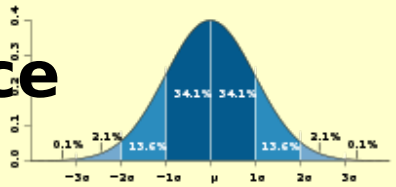
Creating the map “the GRASS way…” 2/2

```
# we simply use the raster map names + the shell variables
# note: re-adjusting variable “dist_sea” from km to m (= map units)
r.mapcalc "t_mean_model2 = $b0 + $b1 * elev_ecad \
                  + $b2 * latitude + $b3/ 1000.0 * dist_from_sea"

r.colors t_mean_model2 color=celsius
```

```
d.mon wx0

d.rast.leg t_mean_model2

d.vect t_mean_europe_meteo

d.vect country_boundaries \
       type=boundary
```

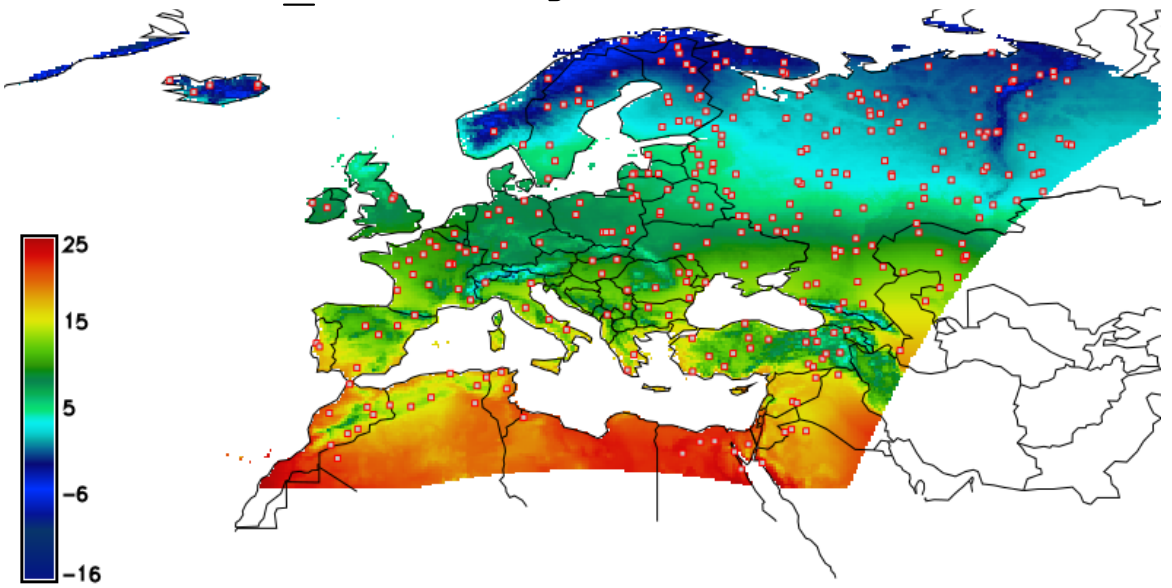


Relationship elevation, latitude, distance from sea and temperature



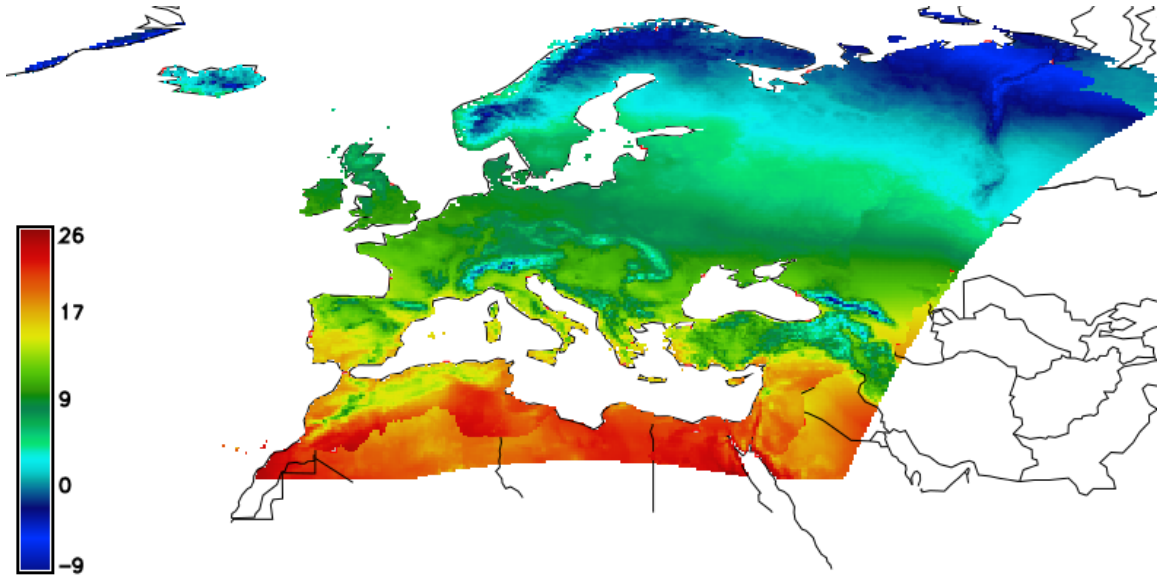

```
# update color table of map to celsius
r.colors tmean.1981_2010.avg color=celsius
d.rast.leg tmean.1981_2010.avg
```

Linear model

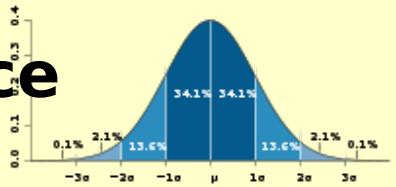


COMPARISON

ECA&D data



Relationship elevation, latitude, distance from sea and temperature



```
# compare simple linear model to real data
r.mapcalc "diff_model_ecad = t_mean_model - tmean.1981_2010.avg"

r.colors diff_model_ecad color=differences

# deg. C differences map:
d.rast.leg diff_model_ecad

r.univar diff_model_ecad
 n: 30311
 minimum: -5.7443
 maximum: 5.54092
 range: 11.2852
 mean: -0.0370348
 mean of absolute values: 1.22533
 standard deviation: 1.5751
 variance: 2.48093
 variation coefficient: -4253.02 %
 sum: -1122.56045289236
```