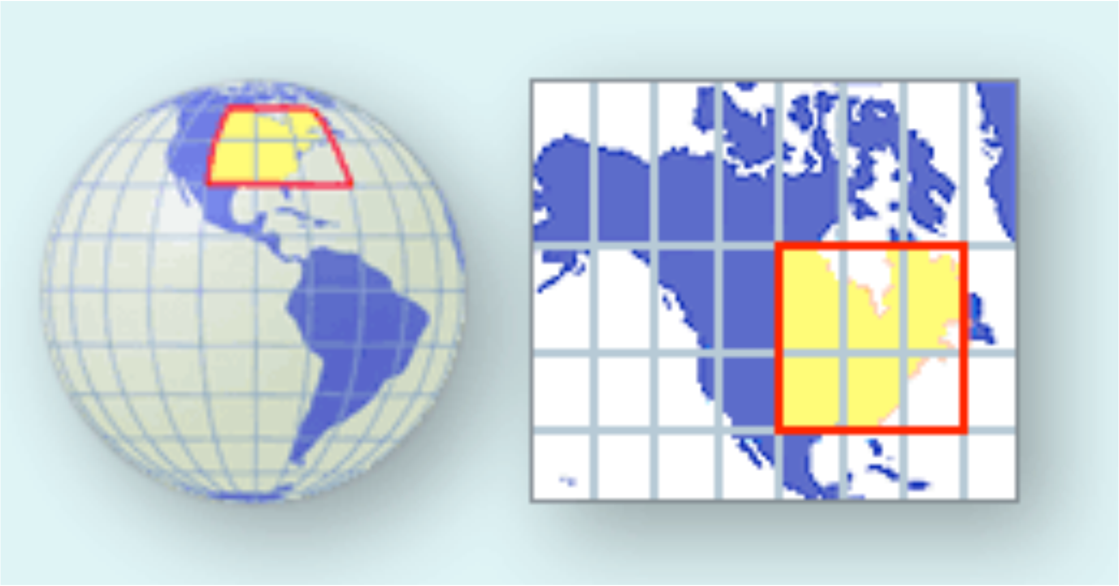
Map Projection Concepts

- Projection is a fundamental component of mapmaking
- Map Projection: attempts to portray the surface of the earth or a proportion of the earth on a flat surface.

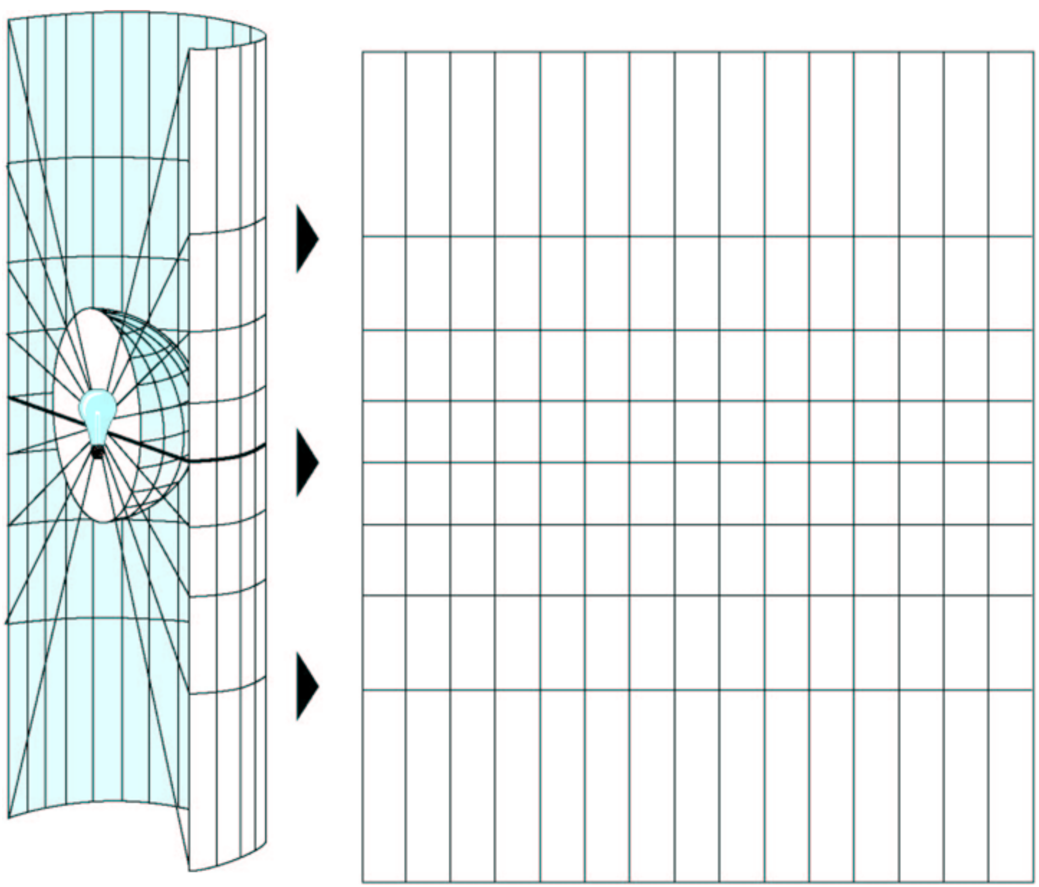


Map Projection Concepts

- Want to go from (ϕ,λ) to a planar position (x,y)
- In other words, want to go from a 3D curved surface to a 2D medium like paper or the computer screen
- Earth's shape is unique – need a good approximation of the earth's surface

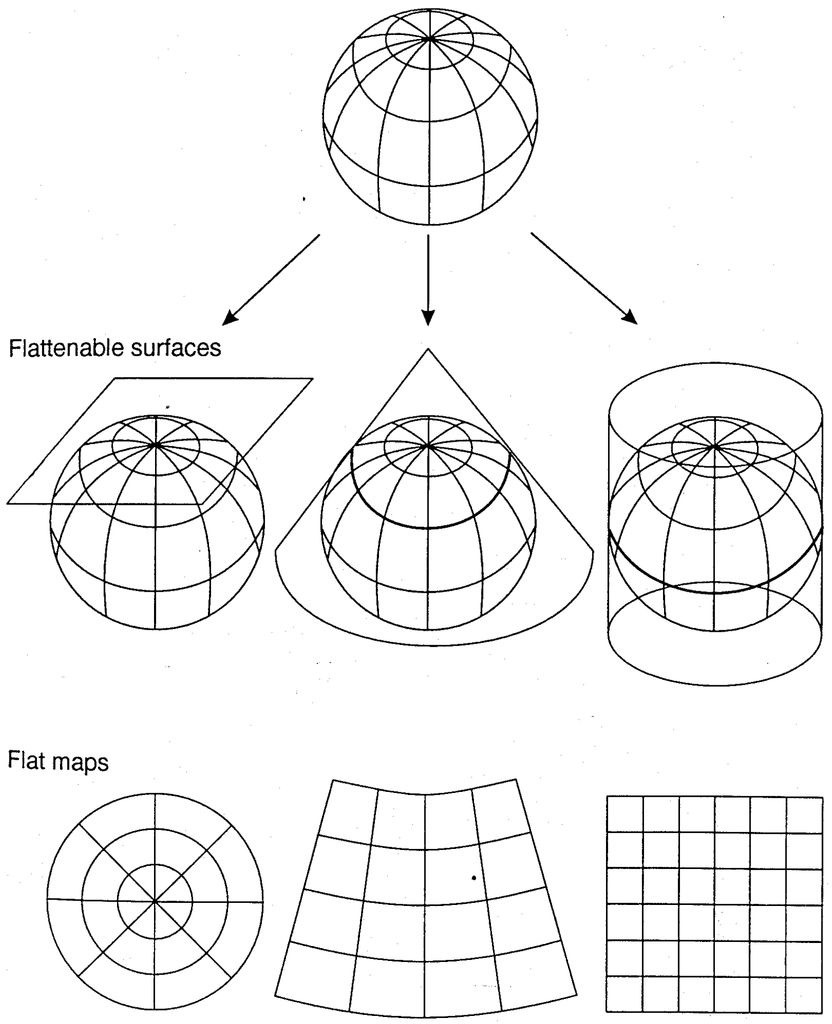
Map Projection Properties

- Projection surface – term comes from the notion of placing a light source in a globe and projecting shadows



Creating a projection starts by creating a point of contact with the 3-D object called a point or line of tangency.

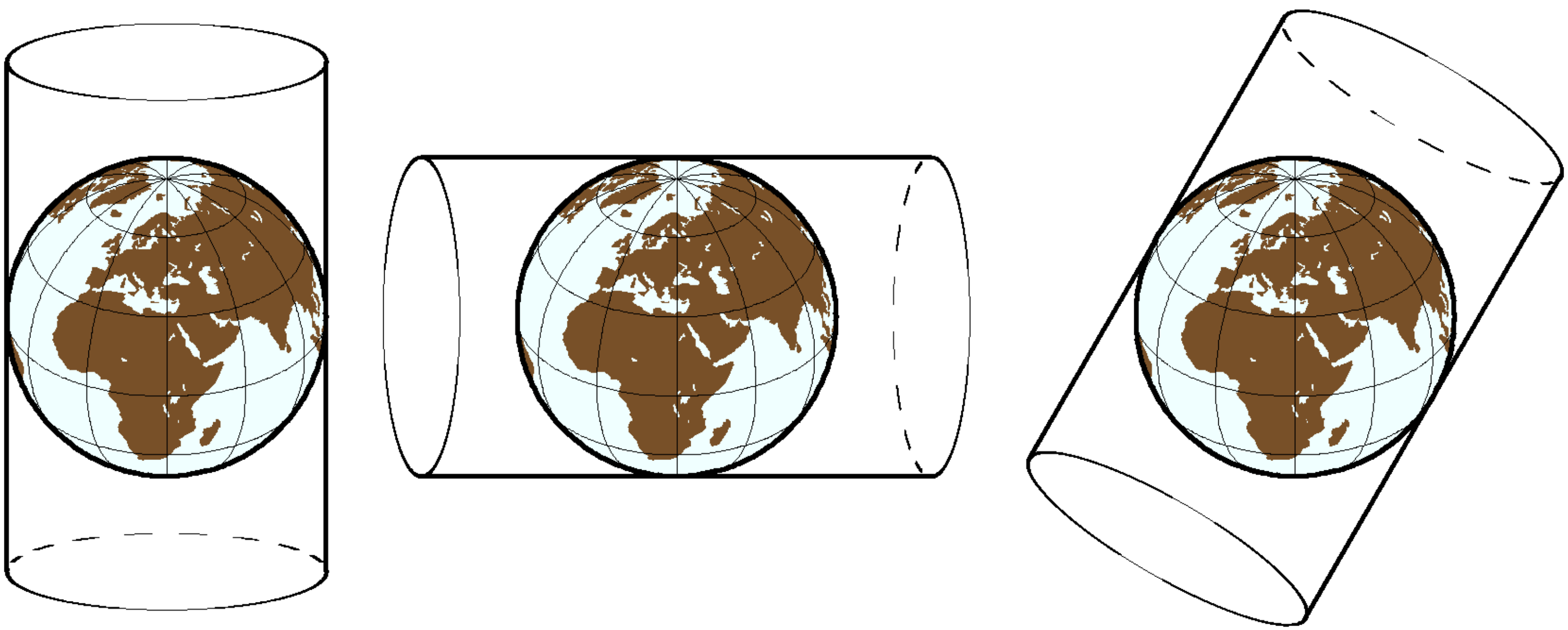
Flattenable Surfaces



- 1. Planar or azimuthal
- 2. Conical
- 3. Cylindrical

Cylindrical projections

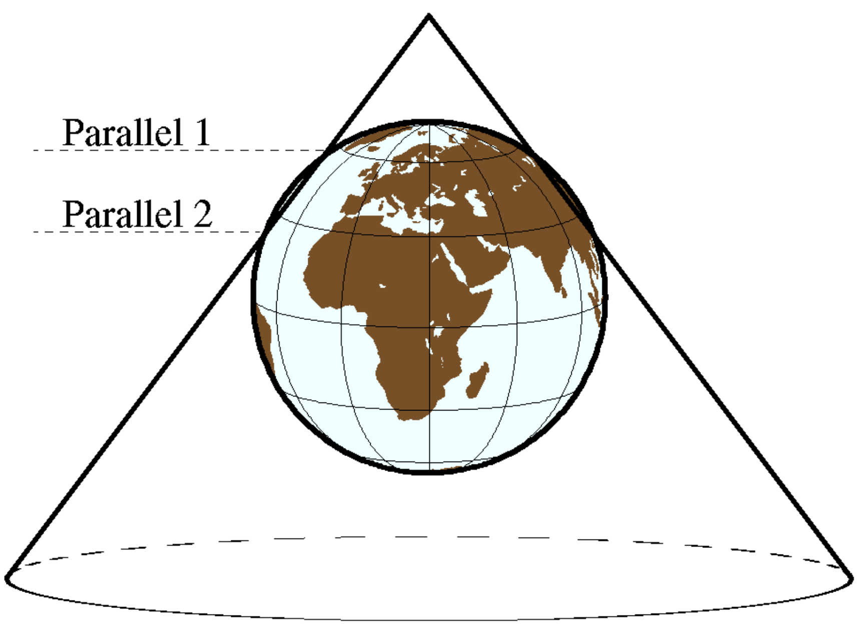
- Points projected from sphere to cylinder
- Cylinder is unrolled to give flat sheet
- May be conformal, equal area, or neither



Normal Transverse Oblique

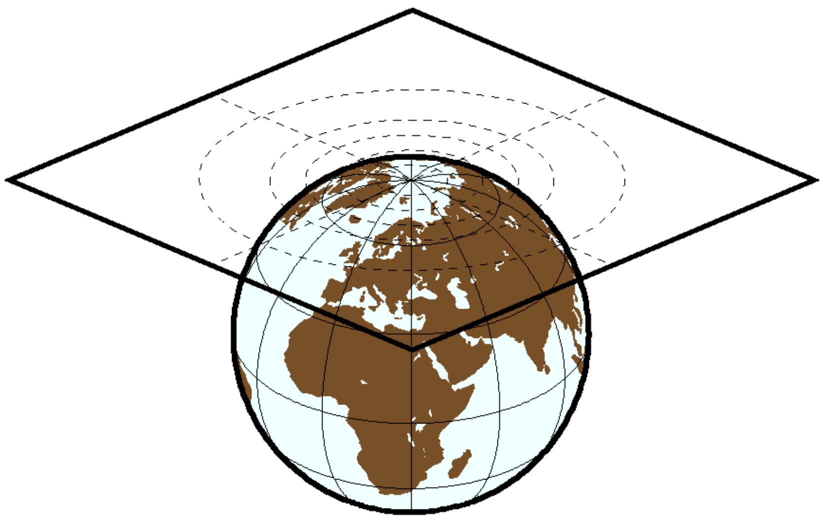
Conical Projections

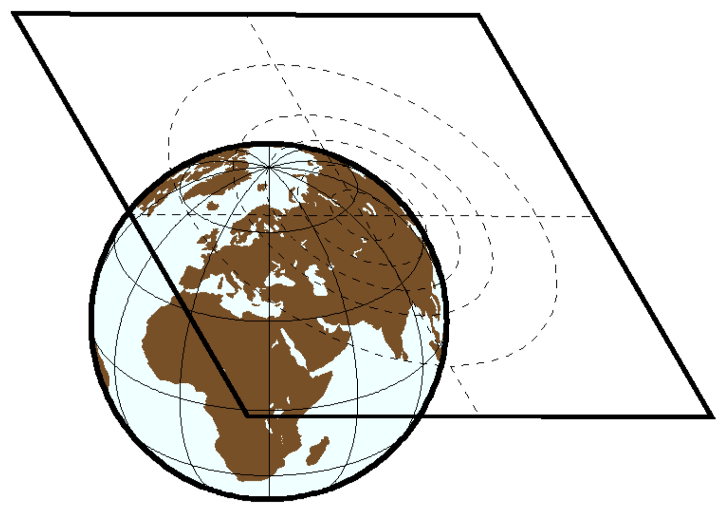
- Cone defined by two standard parallels
- Cone unrolled to yield flat sheet
- Conformal, equal area, or equal distance



Azimuthal projections

- Plane is tangent to point of origin
- Coordinates projected onto plane
- Conformal, equal area, equal distance, other

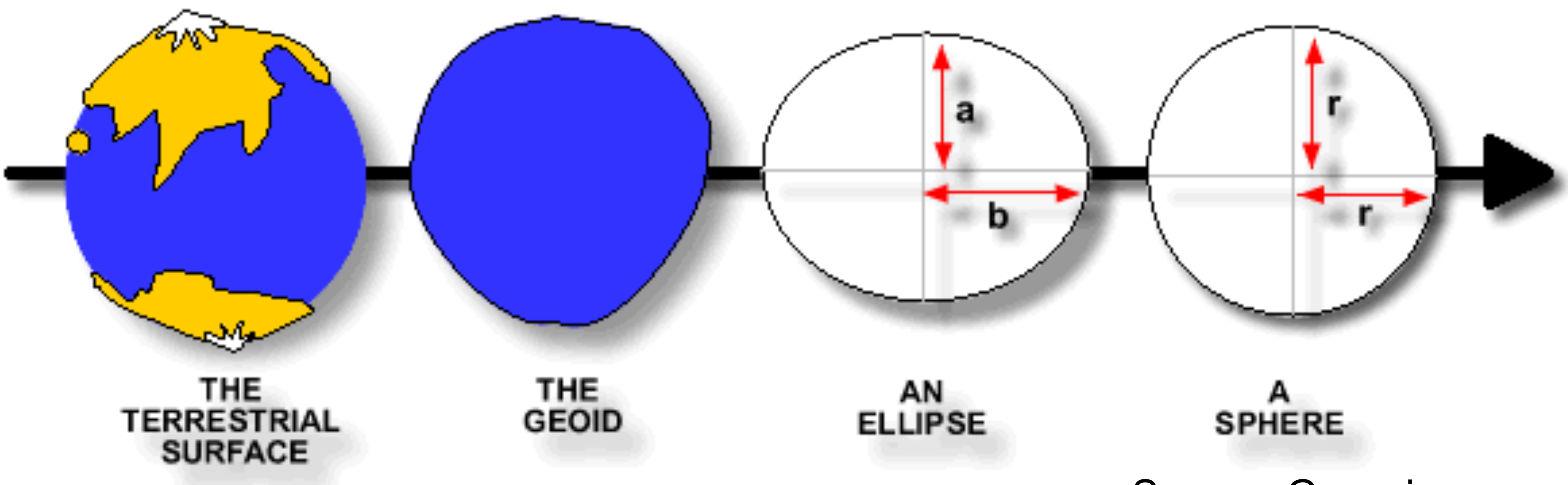




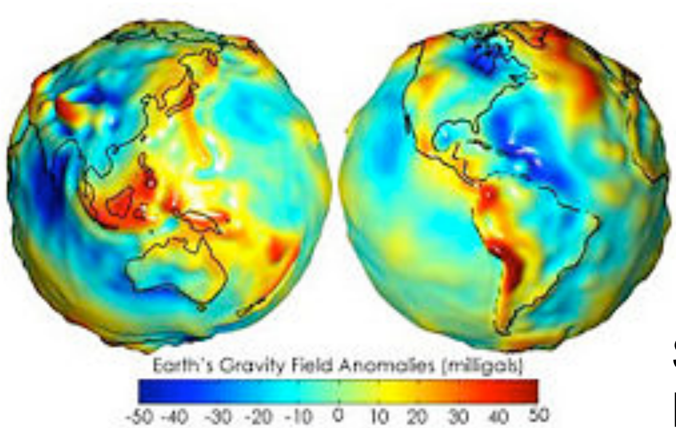
Distortions

- Shape: preserved by conformal projections.
- Area: preserved by equal-area projections.
- Distance: equidistant projections preserve distances between points.
- Direction: azimuthal projections represent distortions correctly with respect to centre.
- (Can't have it all!)

Shape of the Earth

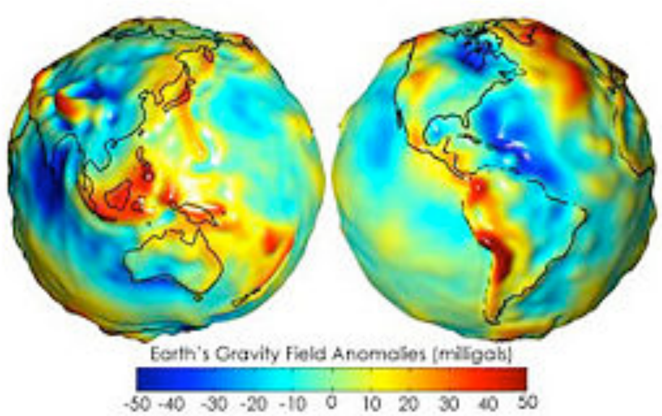


Source: Geoscience Australia

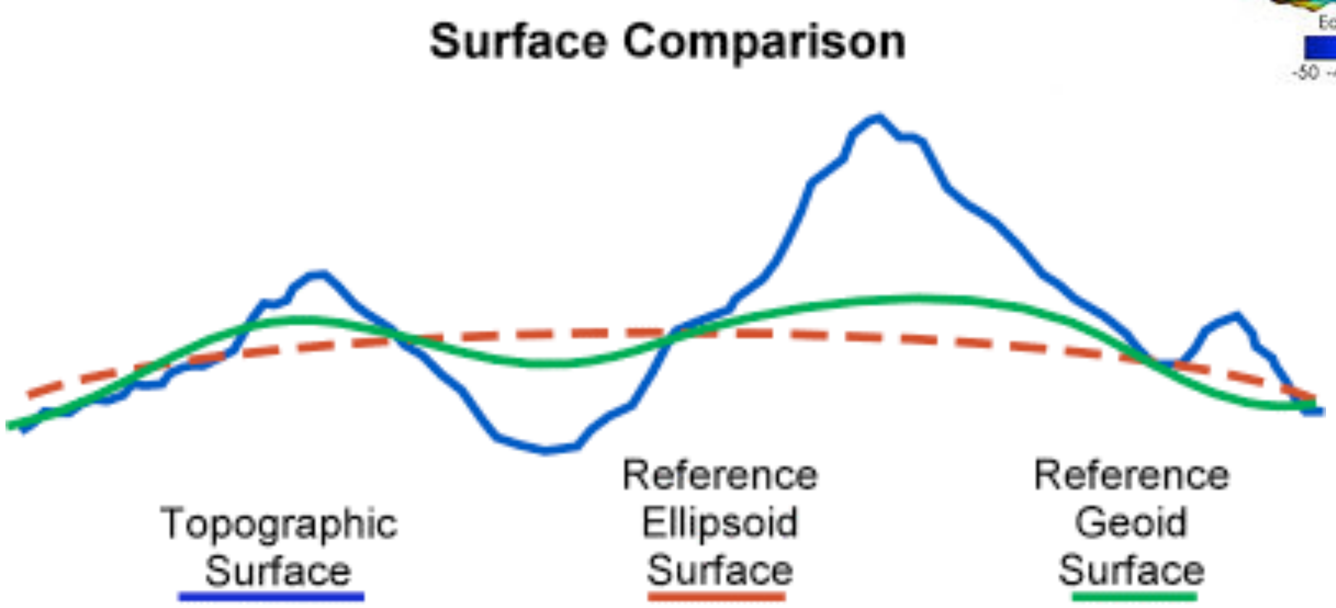


Source: Earth Observatory, NASA

Ellipsoid



Source: Earth Observatory, NASA



Why does this matter?

- Read the following article from The Conversation and watch the embedded movie:
  - https://theconversation.com/australia-on-the-move-how-gps-keeps-up-with-a-continent-in-constant-motion-71883

Class Exercise

Find out which ellipsoid, GMT uses as <u>default</u>.

How will we do this?

Class Exercise

For GMT4 type:

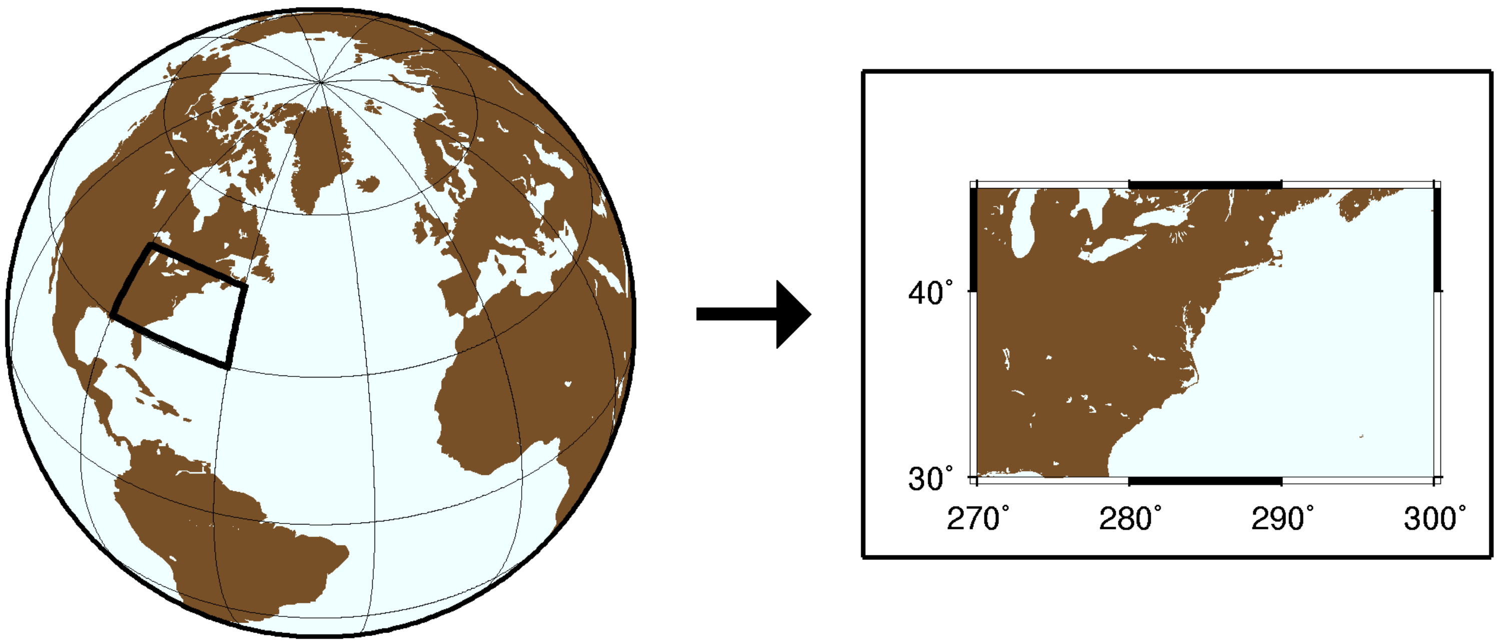
gmtdefaults -D (hint: look for ELLIPSOID)

For GMT5 type:

gmt gmtdefaults (hint: look for PROJ_ELLIPSOID)

What does it say?

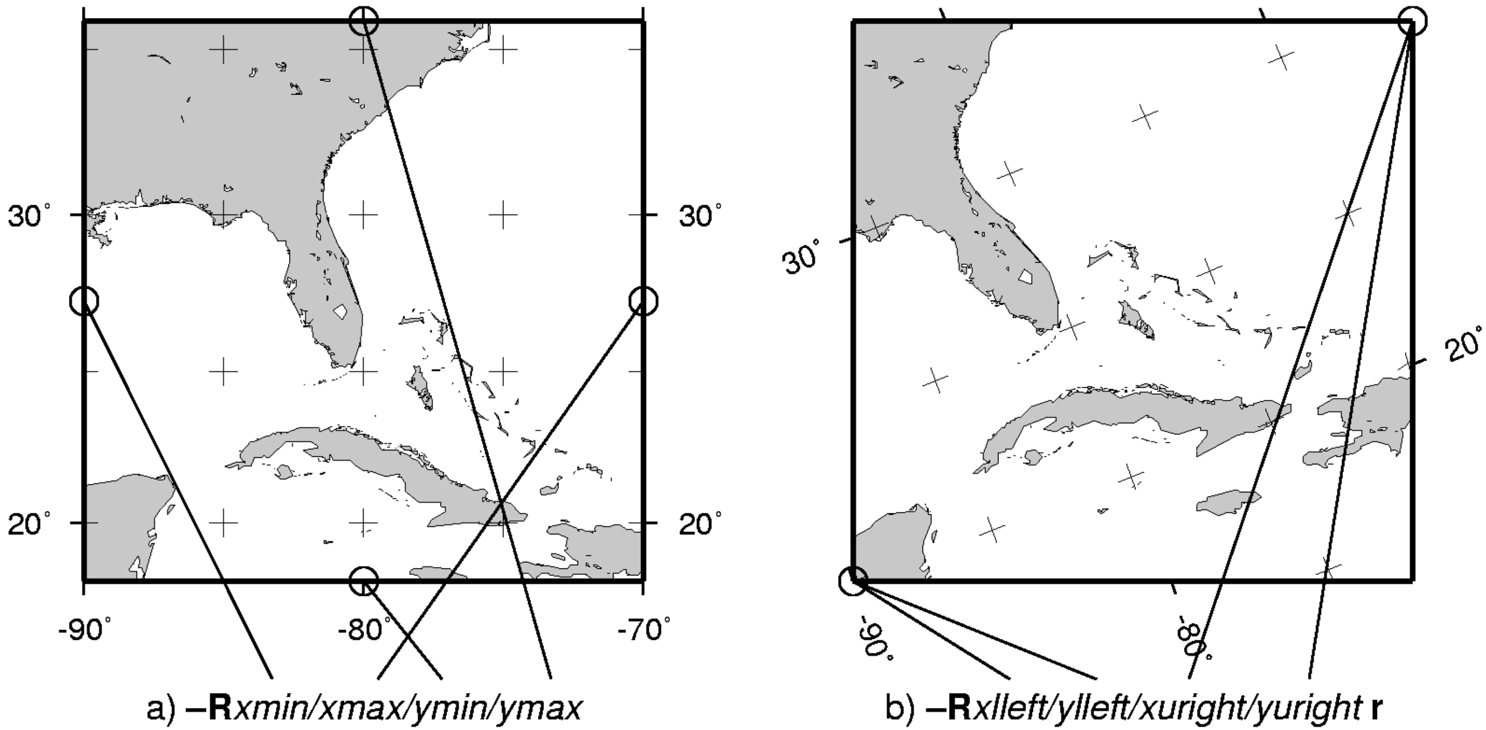
World to plot coordinates



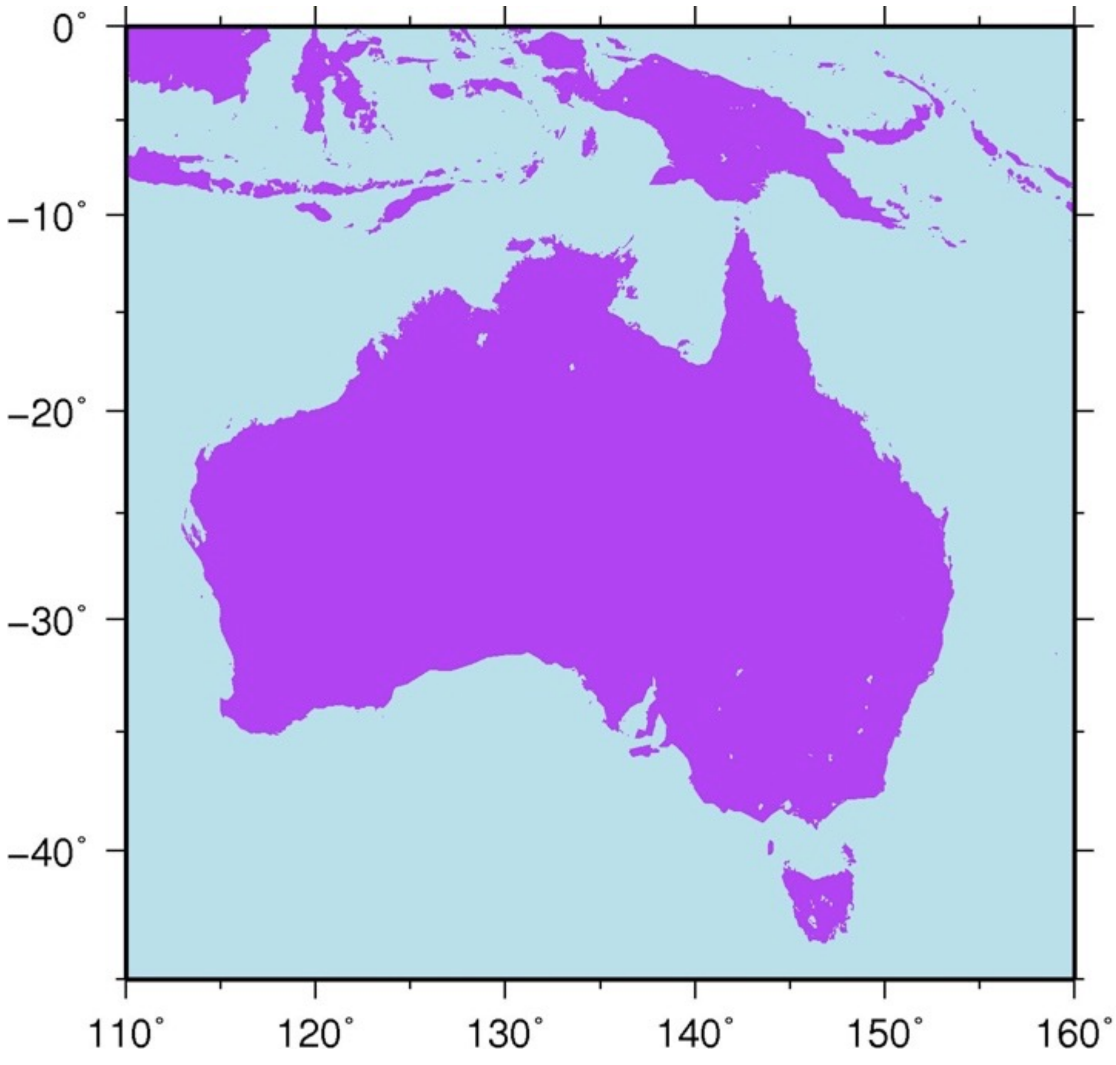
- Must specify region in map coordinates [-R]
- Must specify a map projection [-J]

Specifying Plot Domain [-R]

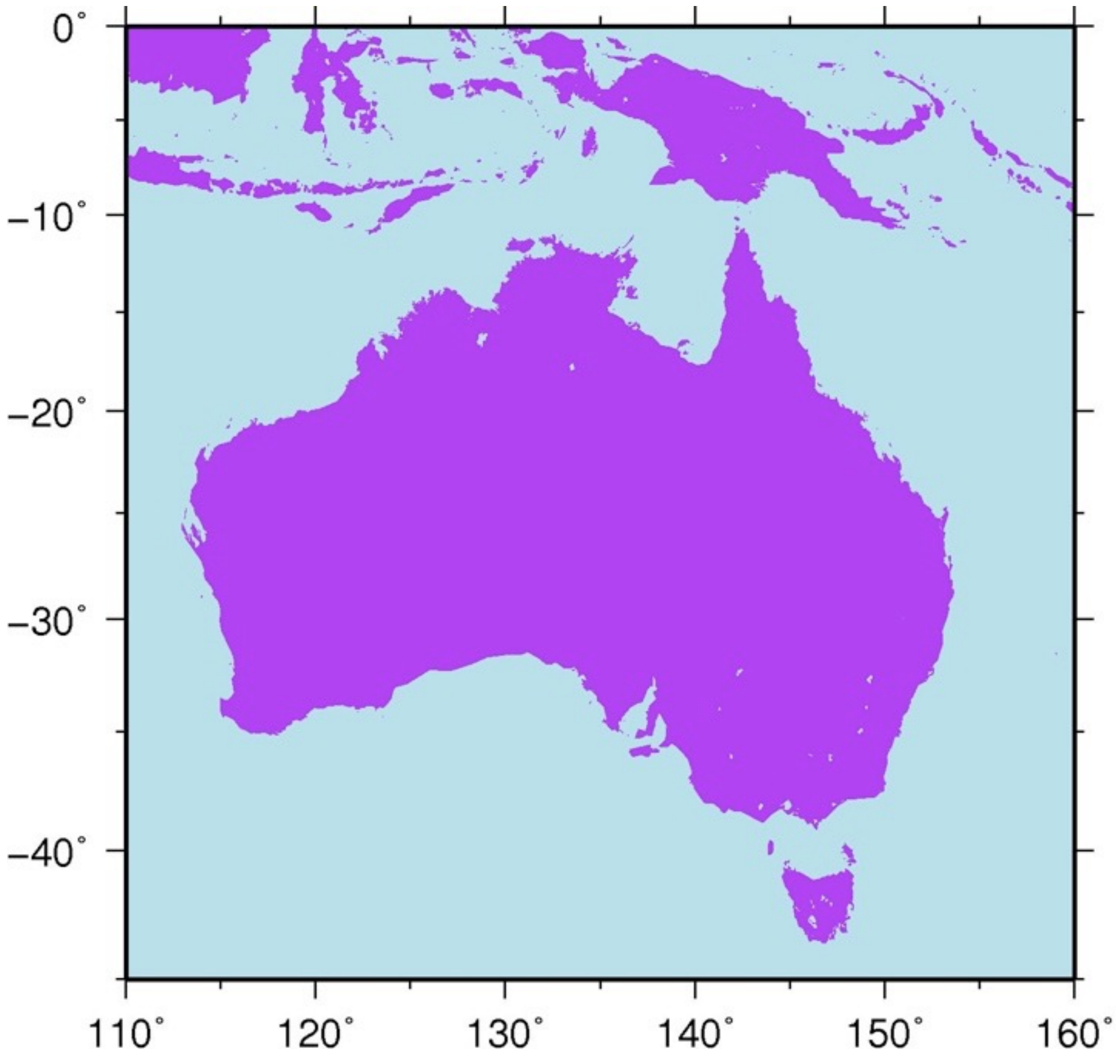
- Specify either min and max coordinates, or
- Specify coordinates of lower left and upper right corners (append r to signal intent)



What are the bounds for this map?



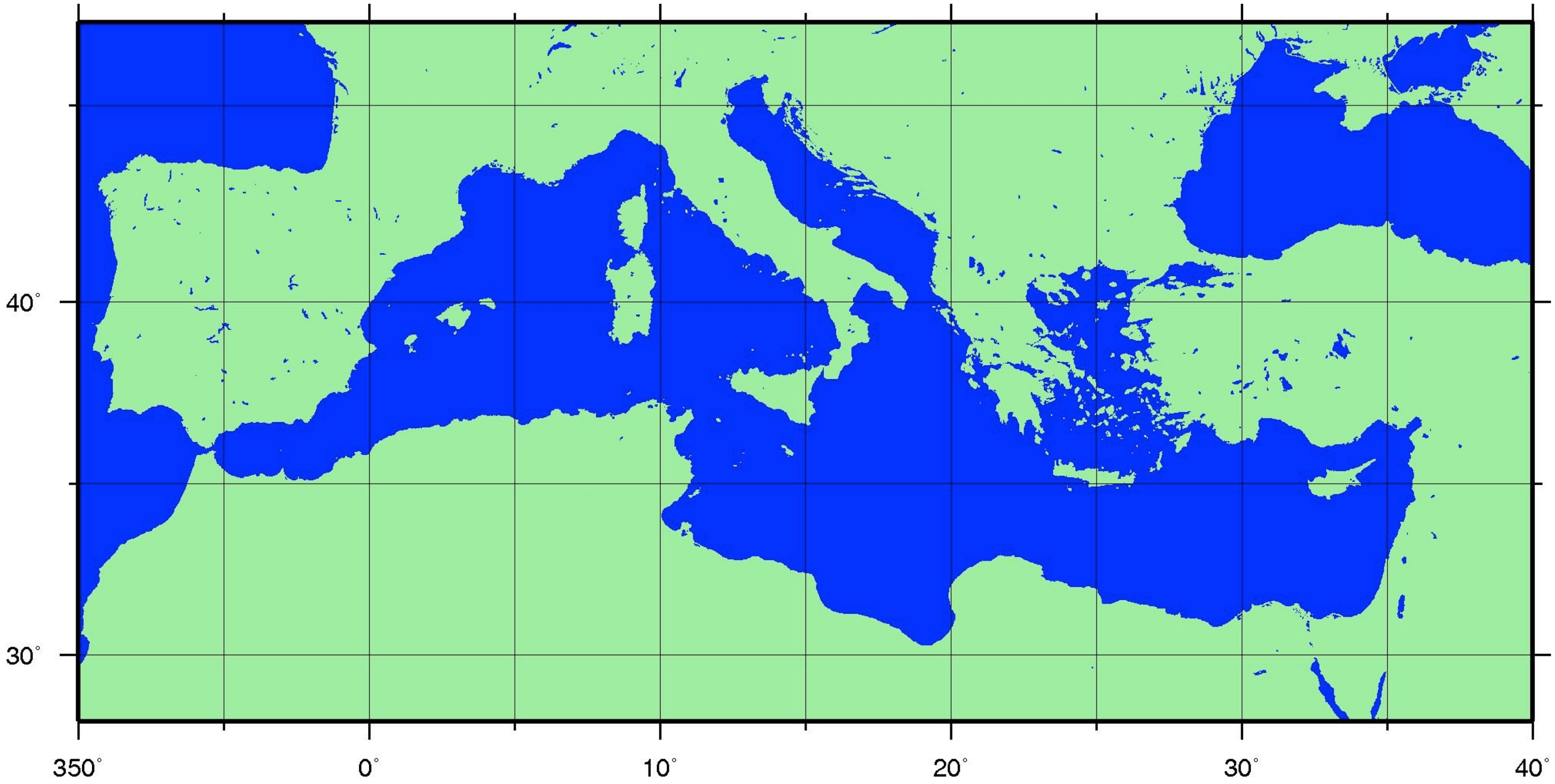
What are the bounds for this map?



-R110/160/-45/0

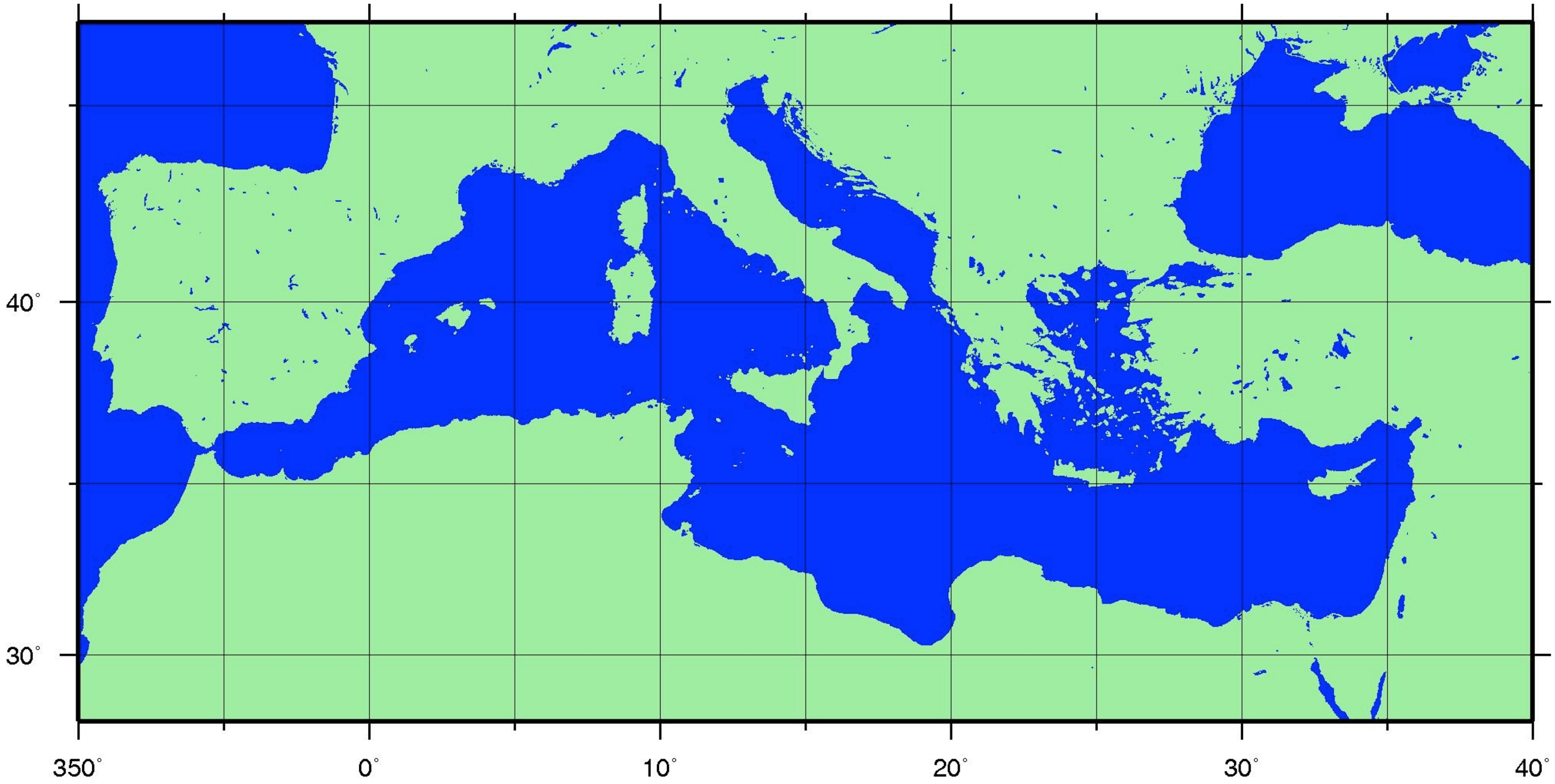
-R110/-45/160/0r

What are the bounds for this map?



What are the bounds for this map?

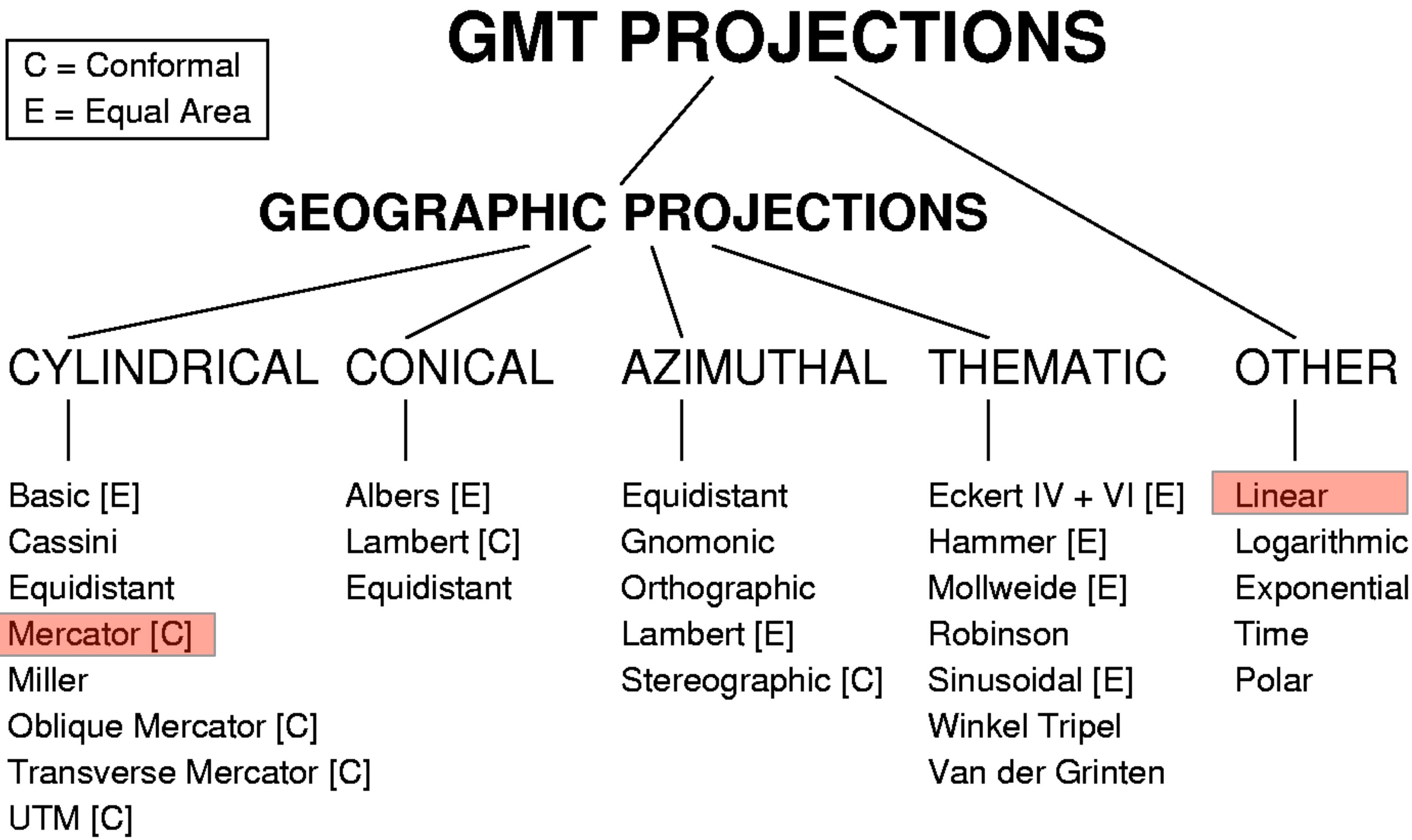
-R-10/40/27.5/47.5 (Cartography) or -R350/400/27.5/47.5 (Mathematically)



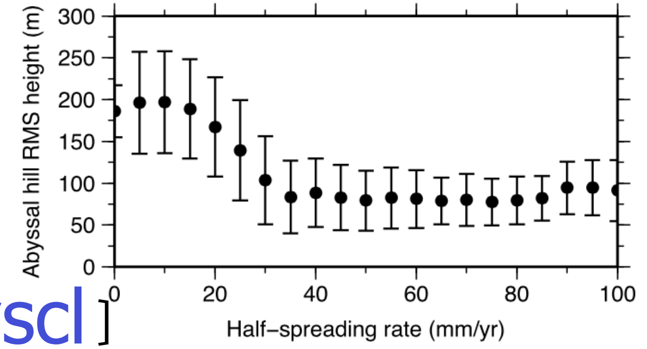
Specifying a map projection [–J]

- Two general approaches:
  - Specifying the map scale:
    - –Jδ[parameters/]scale
  - Specifying the map width:
    - –JΔ[parameters/]width
- Notes:
  - δ or Δ specifies which projection
  - parameters (0 or more) depends on projection
  - Map height is automatically calculated

Selecting Map Projection



Linear Projections



- **–JX**width[/height] or **–Jx**xscl[/yscl]
  - width and/or height, append unit u
  - scale in plot units per user unit
    - Append unit u for plot unit
    - User unit is whatever is given in **–R**
    - scale may also be 1:xxxx
- e.g. –JX10 means that you want a linear plot which will have a width of 10
- e.g. –Jx0.1 means that you want a linear plot with a scale of 0.1

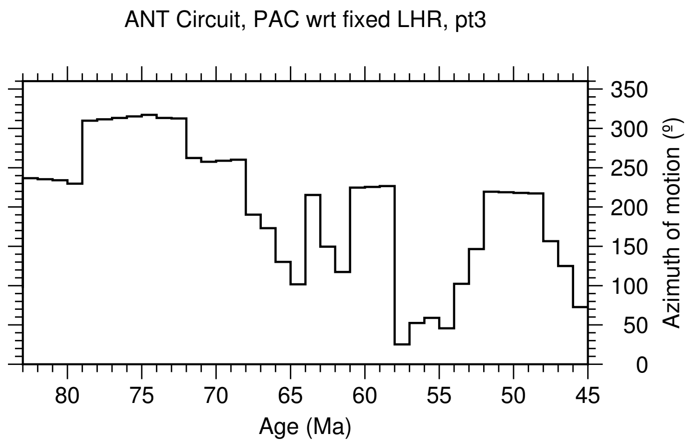
Mercator Projection

- Conformal and Cylindrical projection
- Syntax: **–JM**width or **–Jm**scale
  - Height calculated automatically
  - scale can be
    - plot units per degree
    - 1:xxxxx
- 3-Dimensional projection
- Examples:
  - **–JM**6.5
  - **–Jm**0.2

Drawing and Annotating Frames

To draw a map frame or plot axis, we need to specify 3 items:

- Map Region or data domain [**–R**]
- Projection or transformation [**–J**]
- Boundary annotation information [**–B**]



The -B option from Hell

- Controls annotation-, tick-, and grid-intervals
- Controls primary or secondary axes
- Controls which axes to draw
- Controls axes- and unit-labels
- Controls the plot title
- Simple for maps, harder for $\log_{10}$ and exponential axes, and can be downright ugly for time axes

The general syntax for –B

–B[p|s]xinfo[/yinfo][:."Title":][W|w][E|e][S|s][N|n]

Optionally specify primary or secondary axes information [p]

xinfo or yinfo means:

info[:"axis label":][:,"unit label"]

info is defined as one or more of:

[**t**]stride[<u>u</u>]

Interpretation of [**t**]stride[u]:

- **t** specifies the axis element
- stride sets the actual interval
- **u** indicates the interval unit

Recognized **t** settings:

Flag	Description
a	Annotation spacing
f	Frame tick spacing
g	Gridline tick spacing

More on -B

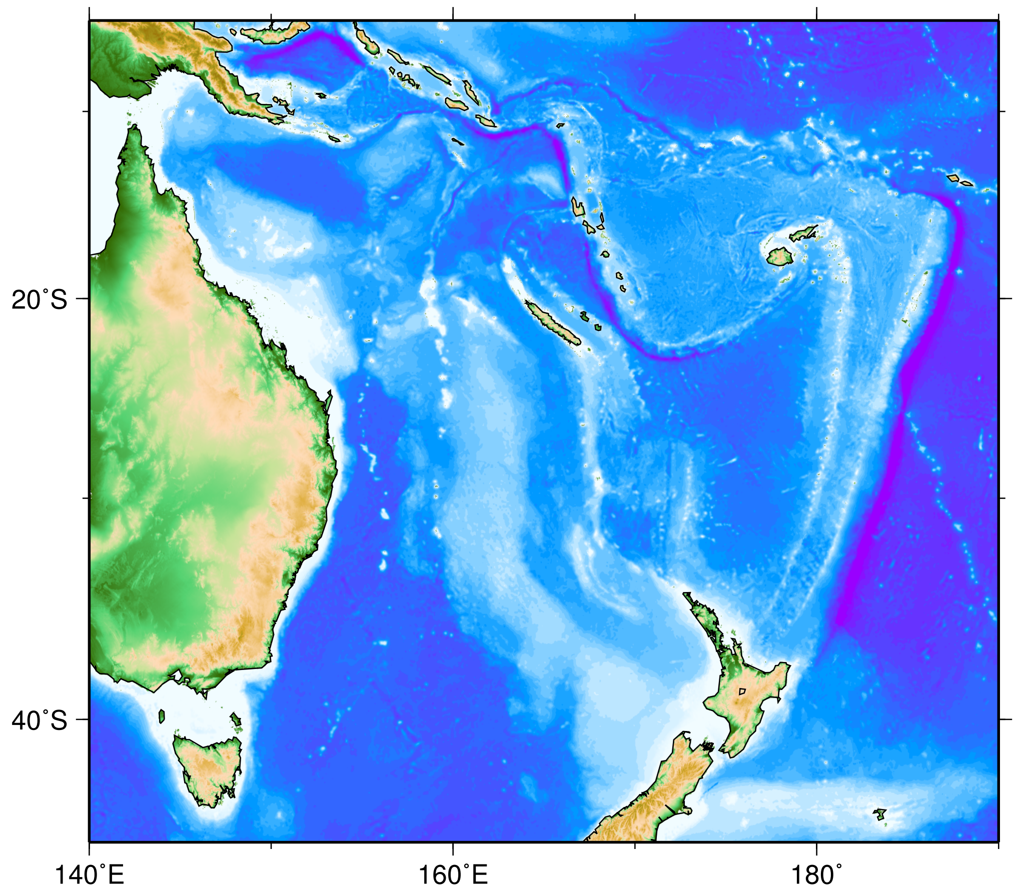
- By default, annotations and labels are plotted for all axes but this can be controlled
- [W|w][E|e][S|s][N|n][Z|z[+]]
- Uppercase means plot all information
- Lowercase means only plot outline
- Exclusion means do not plot anything

Examples of -B

- -Ba10f5g10
- -B a10f5g10:"Sea level"::,m:
- -Ba30f10g30/a10f5g10
- -Ba10f1:"Time (millions of years)":/ a100f10:"Sea level (m)":.:"Long-term Sea level for the last 200 Million Years":WS

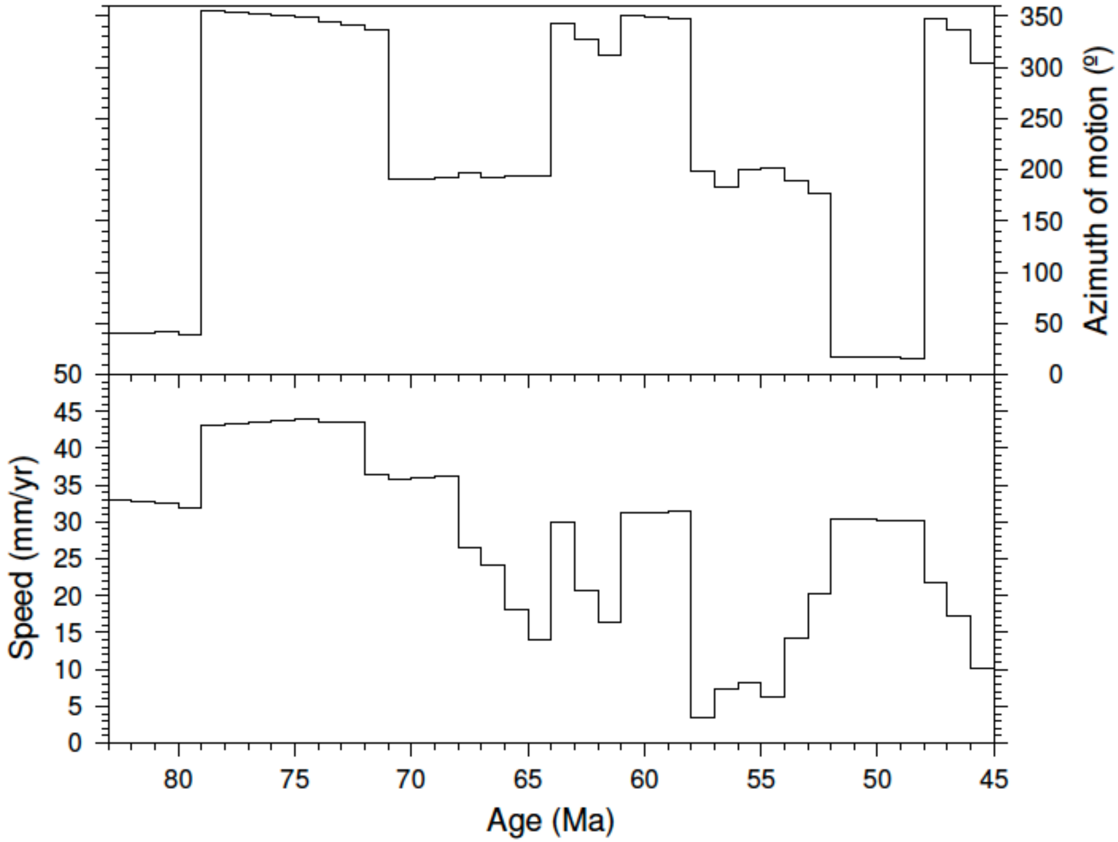
Example...

- -Ba20f10SWen



Example… harder

- -Ba5f1:"Age (Ma)":/a5f1:"Speed (mm/yr)":SWe
- -Ba5f1/a50f10:"Azimuth of motion (\272)":Esw
- -Ba1000N

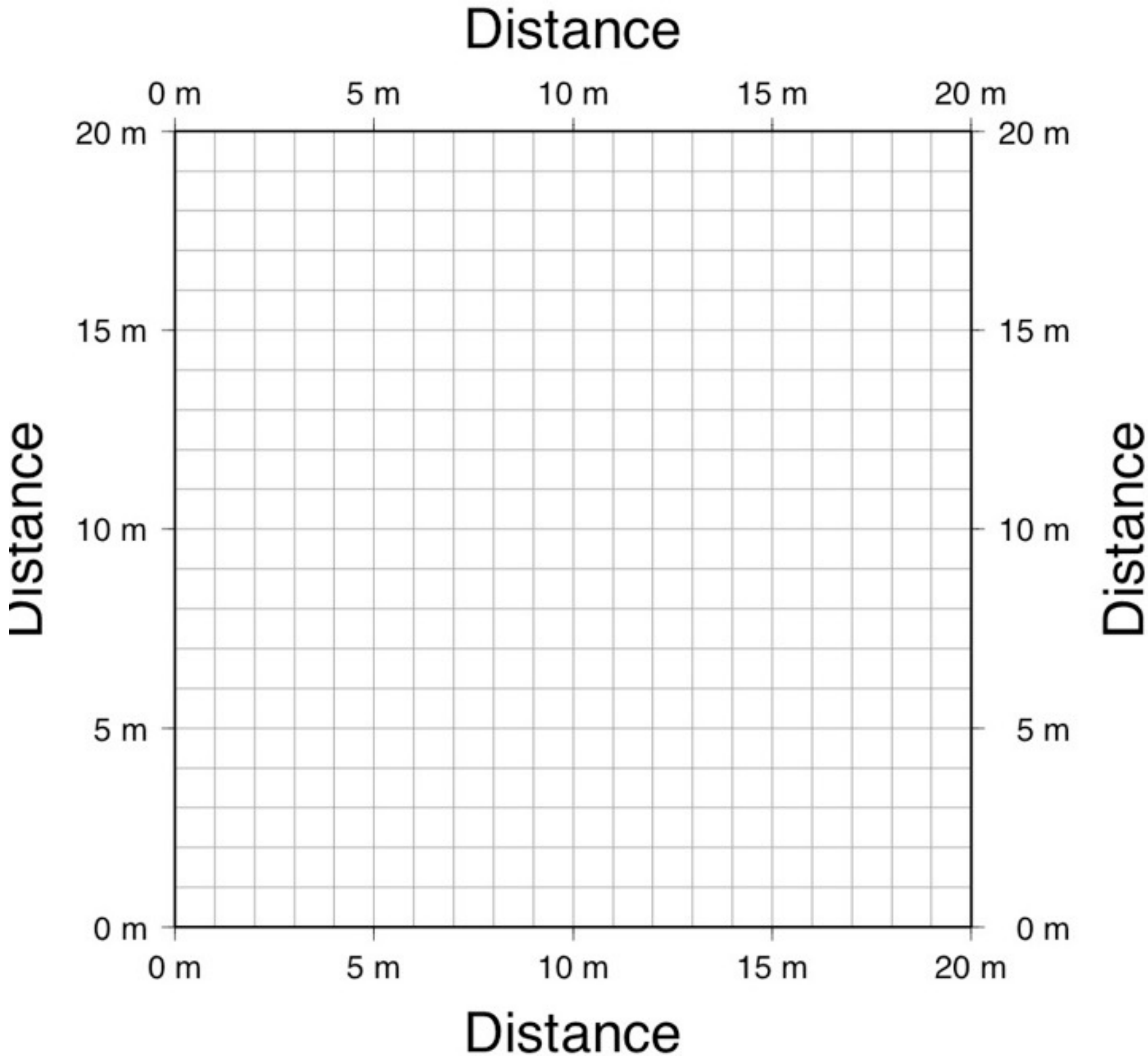


Map exercise 3a

Task: Use psbasemap to make 12cm square plot for a 20 x 20 meter area, annotate every 5 meters, gridlines every 1 meter, label the axes “Distance”, with unit “m”

```
psbasemap -R0/20/0/20 -JX12 \
-Ba5g1:"Distance"::,m: > plot.ps
```

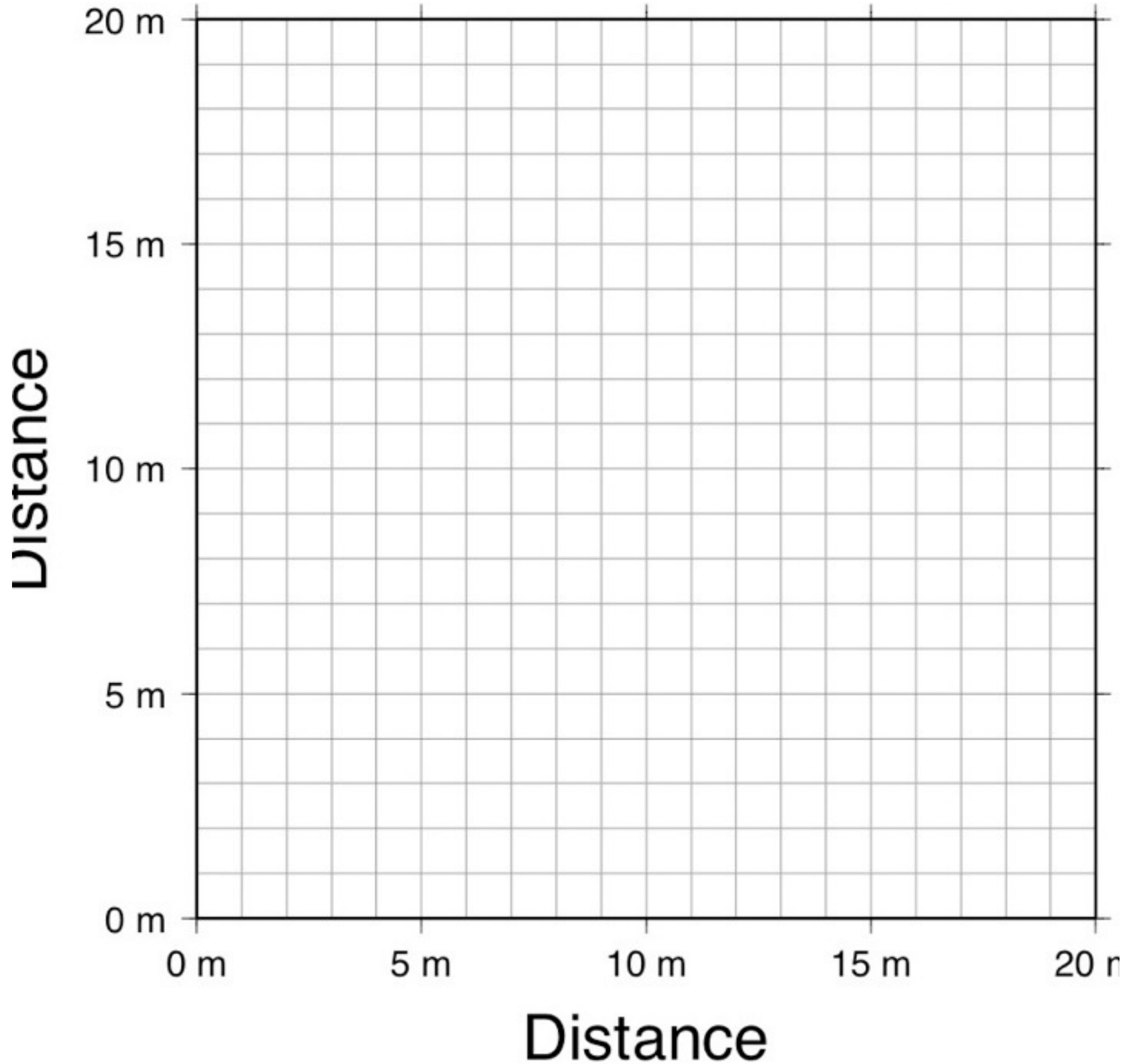
- Use **–P** for a Portrait plot
- If needed type pstopdf plot.ps and open the plot.pdf file
- gmt4 ps2raster –Tf –A –V –E300 plot.ps


Distance
0 m
5 m
10 m
15 m
20 m
20 m
15 m
10 m
5 m
0 m
Distance
Distance
0 m
5 m
10 m
15 m
20 m
Distance

Map exercise 3b

Task: Use psbasemap to make 12cm square plot for a 20 x 20 meter area, annotate every 5 meters, gridlines every 1 meter, label the axes "Distance" but only annotate on the left and bottom axes. Make the plot portrait.

- Call the plot plot2.ps

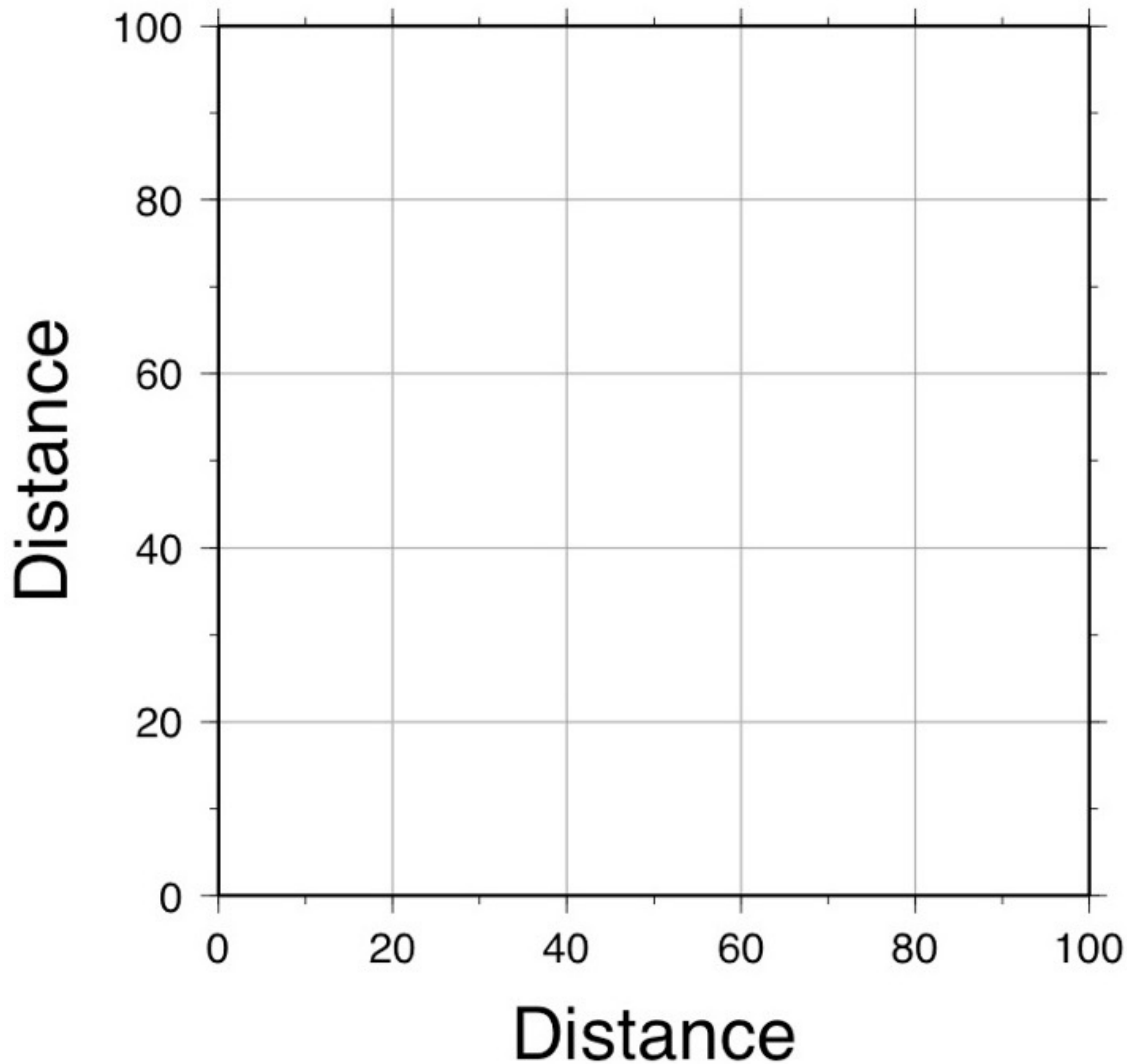

20 m
15 m
10 m
5 m
0 m
Distance
0 m
5 m
10 m
15 m
20 m
Distance

Map exercise 3c

Task: Use psbasemap to make 10cm square plot for a 100 x 100 meter area, annotate every 20 meters, gridlines every 20 meters, tickmarks every 10 meters. Label the axes "Distance" but only annotate on the left and bottom axes. Add a title to the plot called "My distance Plot". Make the plot portrait.

- Call the plot plot3.ps

My Distance Plot

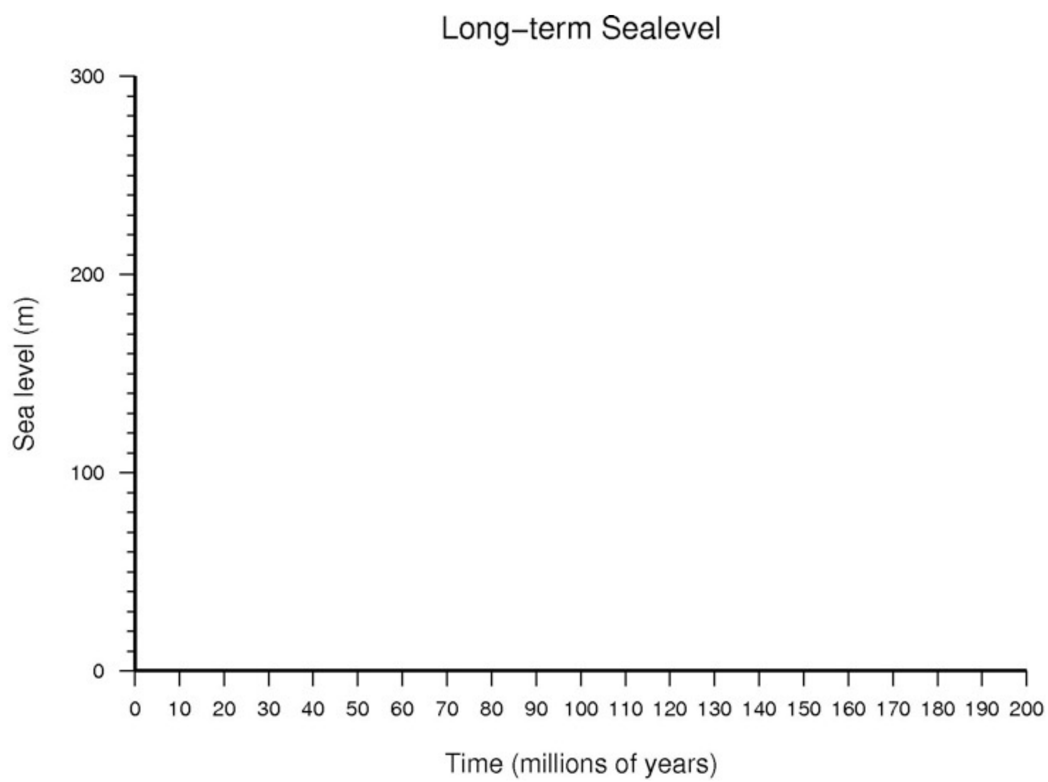


Map exercise 3d

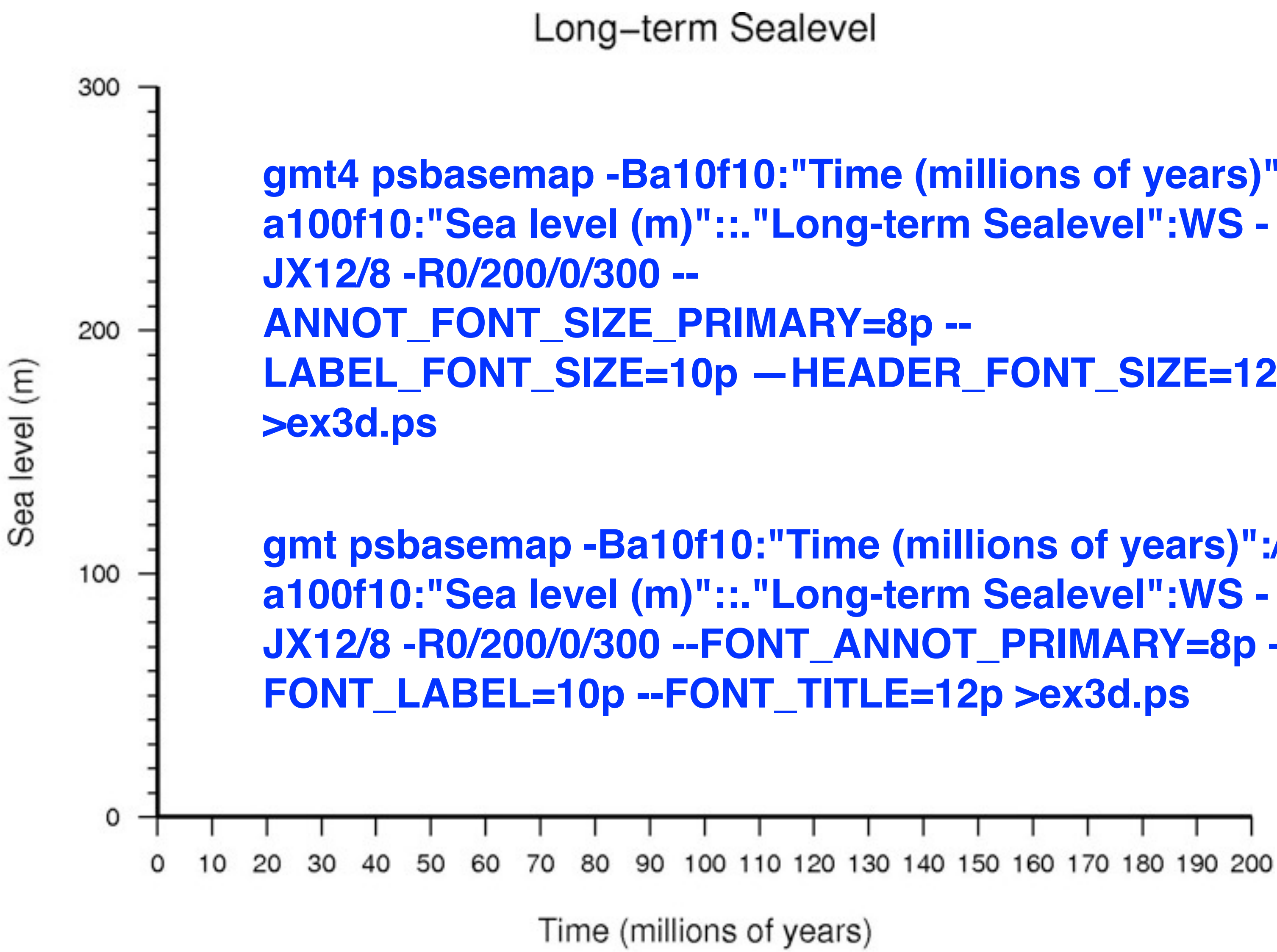
Task: Use psbasemap to make the following plot

(For GMT4 add --ANNOT_FONT_SIZE_PRIMARY=8p --LABEL_FONT_SIZE=10p --HEADER_FONT_SIZE=12p to your psbasemap line)

(For GMT5 add --FONT_ANNOT_PRIMARY=8p --FONT_LABEL=10p --FONT_TITLE=12p to your psbasemap line)



Map exercise 3d




```
gmt4 psbasemap -Ba10f10:"Time (millions of years)":/
a100f10:"Sea level (m)"::."Long-term Sealevel":WS -
JX12/8 -R0/200/0/300 --
ANNOT_FONT_SIZE_PRIMARY=8p --
LABEL_FONT_SIZE=10p —HEADER_FONT_SIZE=12p
>ex3d.ps
```

```
gmt psbasemap -Ba10f10:"Time (millions of years)":/
a100f10:"Sea level (m)"::."Long-term Sealevel":WS -
JX12/8 -R0/200/0/300 --FONT_ANNOT_PRIMARY=8p --
FONT_LABEL=10p --FONT_TITLE=12p >ex3d.ps
```

Map exercise 3e

- Task: Create a basemap that corresponds to a Mercator projection, region of interest being the Australian continent, map width of 12 cm with annotations, tickmarks and gridlines every 10 degrees latitude and every 20 degrees longitude. The title of the basemap should be "Australia should be here".

Australia should be here