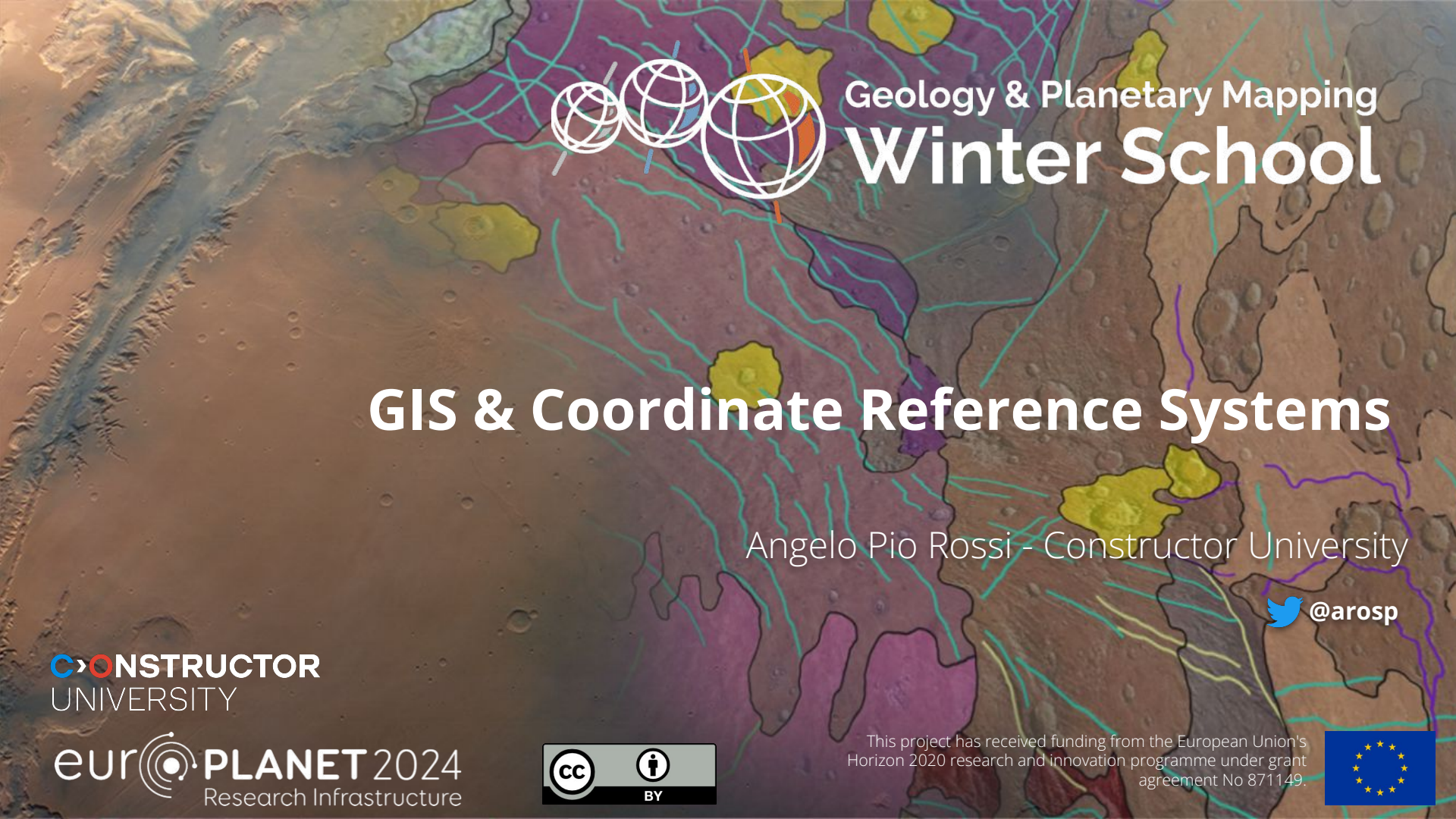

EUROPLANET 2024
Research Infrastructure



Geology & Planetary Mapping
Winter School

GIS & Coordinate Reference Systems

Angelo Pio Rossi - Constructor University

@arosp

CONSTRUCTOR UNIVERSITY

EUROPLANET 2024 Research Infrastructure

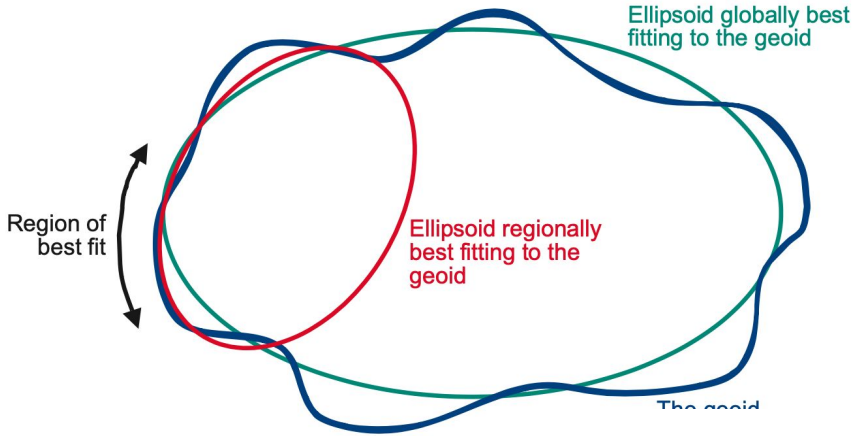
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149.

GIS, CRS, and map projections

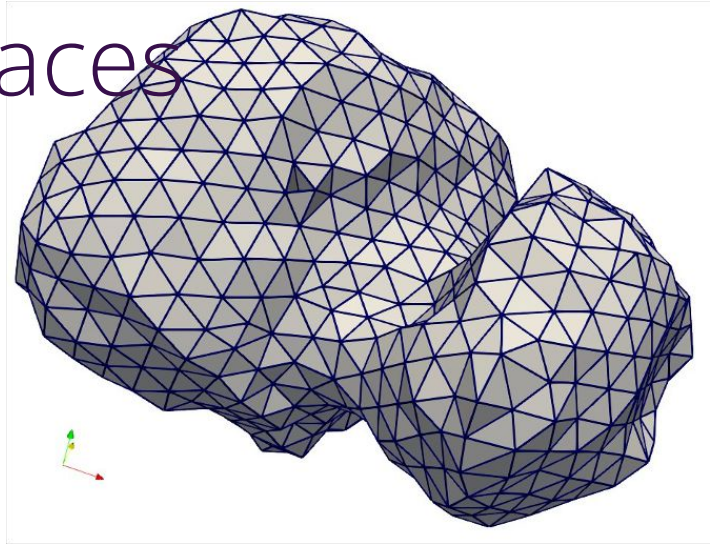
Many definitions, but to keep it short: ~

- **Map projection**: A model of the surface
- **CRS**: A model of the surface, and its reference body
- **GIS**: A computing / management/ visualisation / analysis system to deal with:
  - data with a CRS = (digital/ised) **geospatial data**

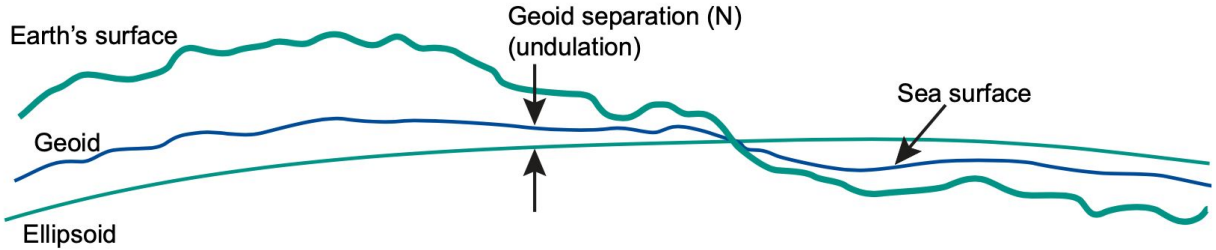
Reference surfaces



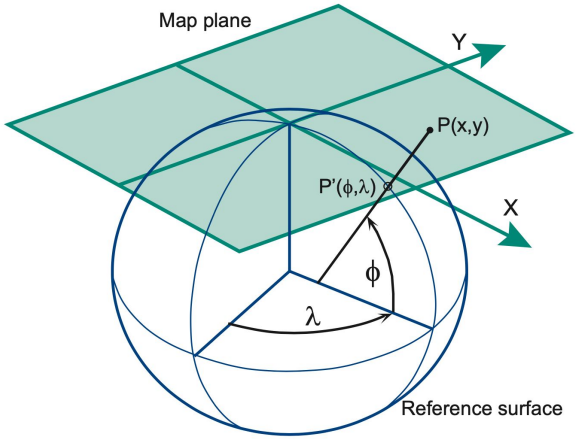
Source: Knippers (2009)

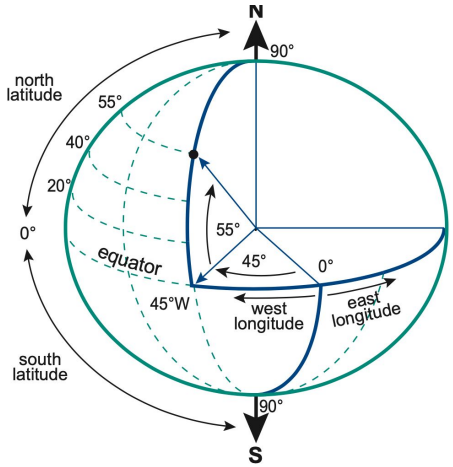


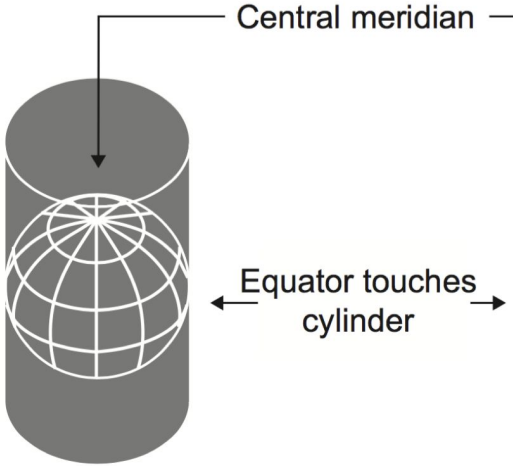
Source: L. Penasa

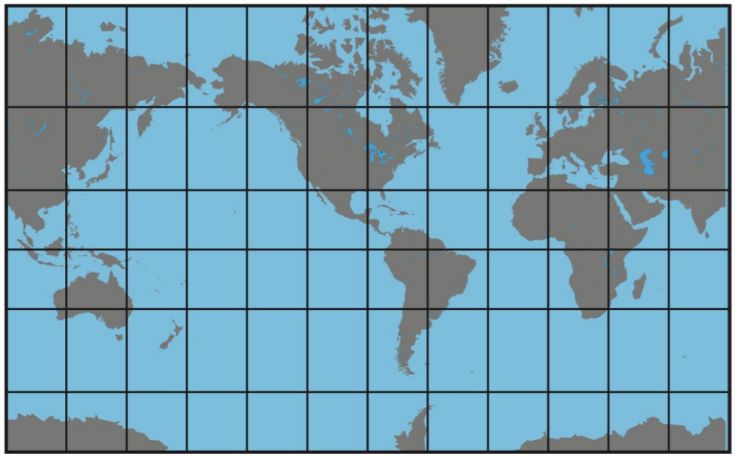


Map projections



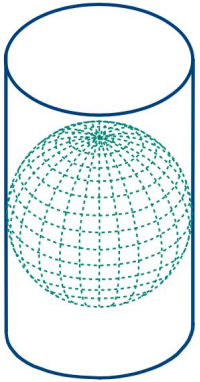




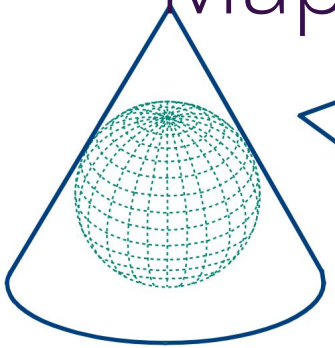


Source: Knippers (2009); Hare et al. (2018)

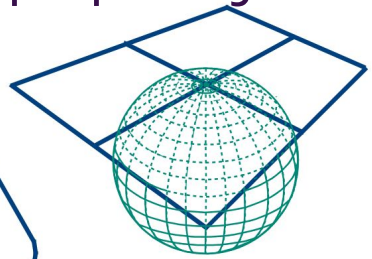
Map projection classes



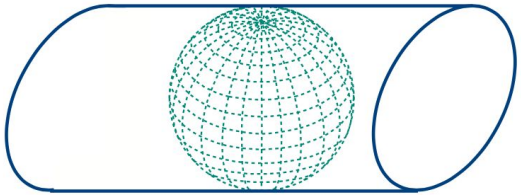
Cylindrical



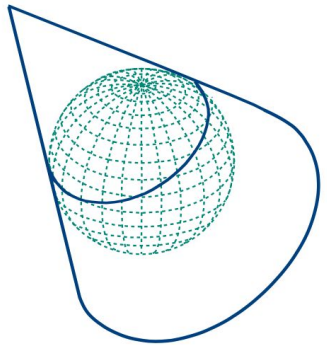
Conical



Azimuthal



Transverse cylindrical

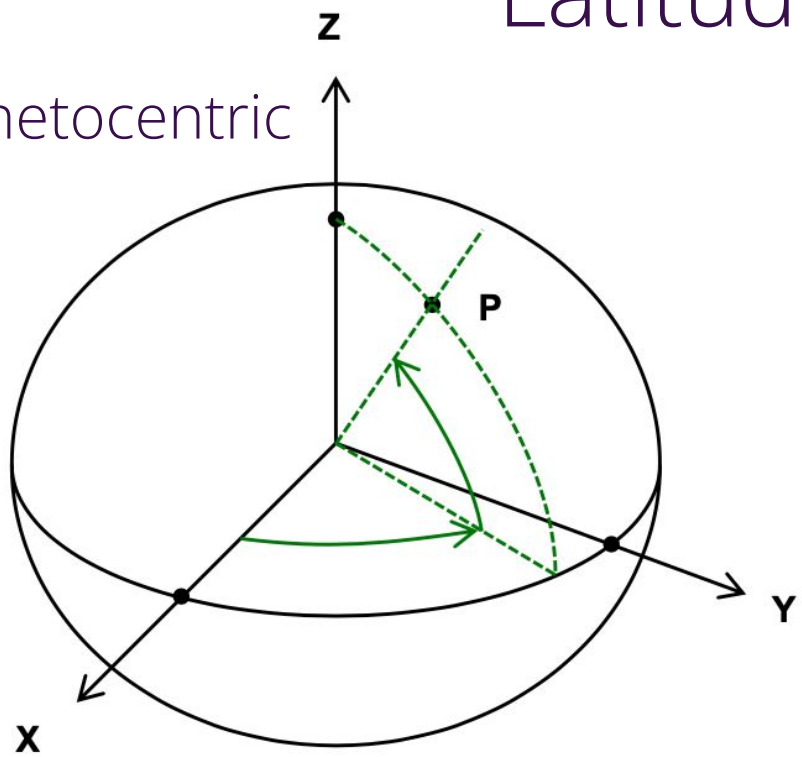


Oblique conical

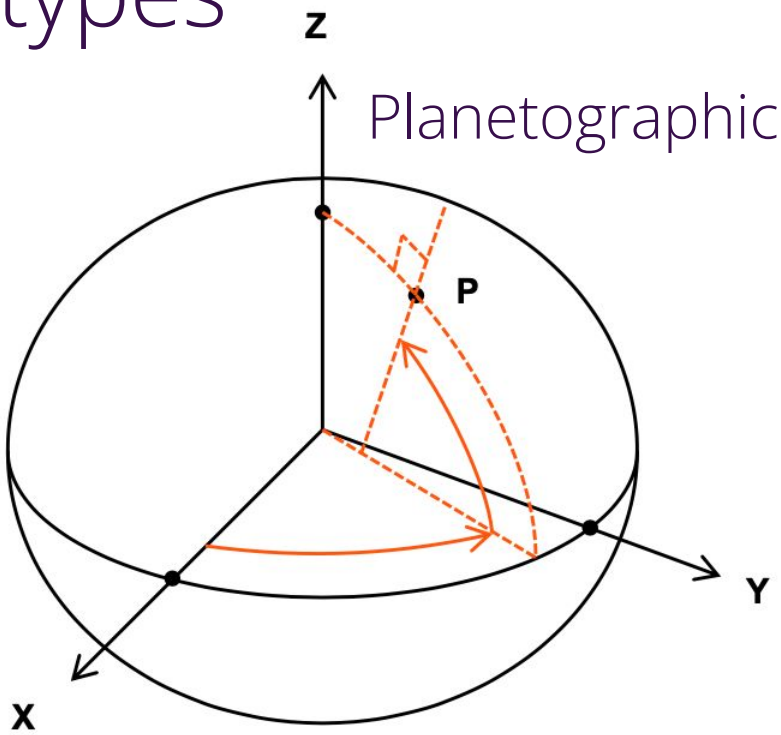
Source: Knippers (2009)

Latitude types

Planetocentric

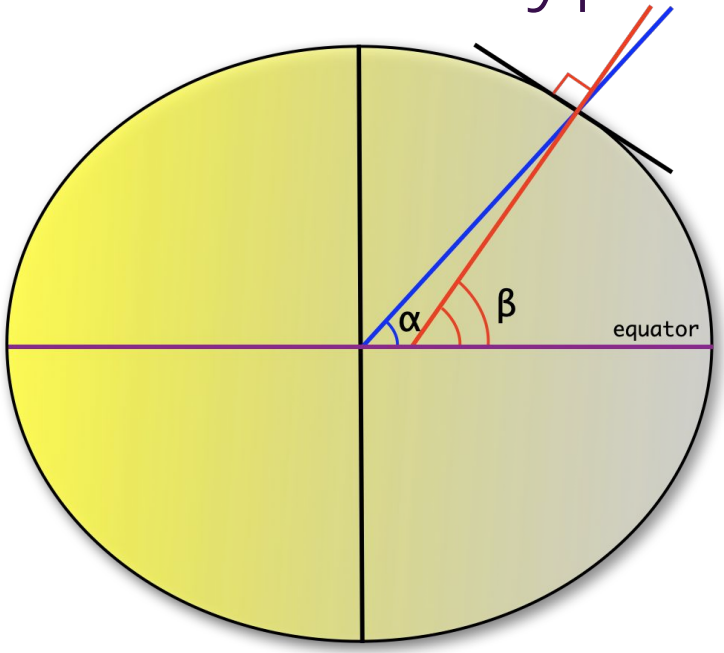


Planetographic



Source: NAIF/JPL (2022)

Latitude types



Latitude:

α = planetocentric

β = planetographic

of course, if:

```
A_AXIS = 3396.0 km
B_AXIS = 3396.0 km
C_AXIS = 3396.0 km
```

α = β

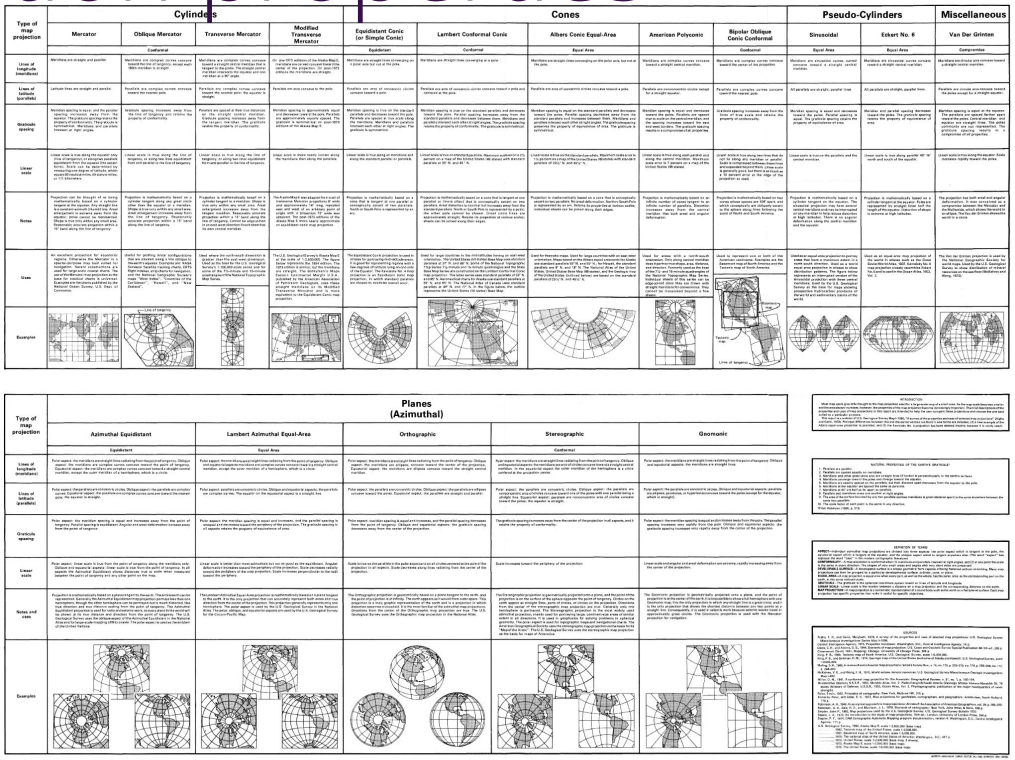
and life is easier...

Source: Hare et al. (2018)

Map projection properties

- Area → Equal-area
- Angle → Conformal
- Distance → Equidistant

Map projection properties

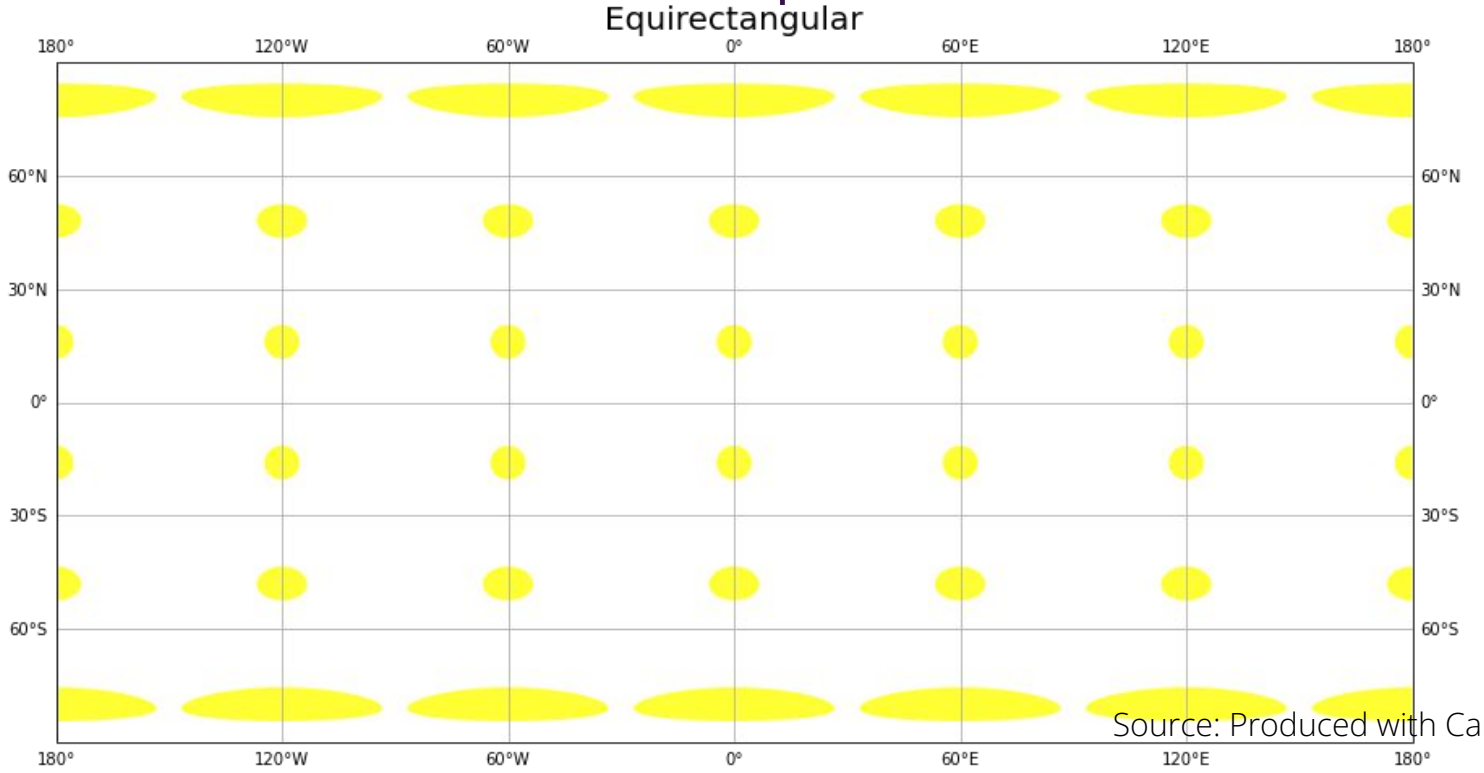


Source: Snyder (1987)

https://pubs.usgs.gov/pp/1395/plate-1.pdf

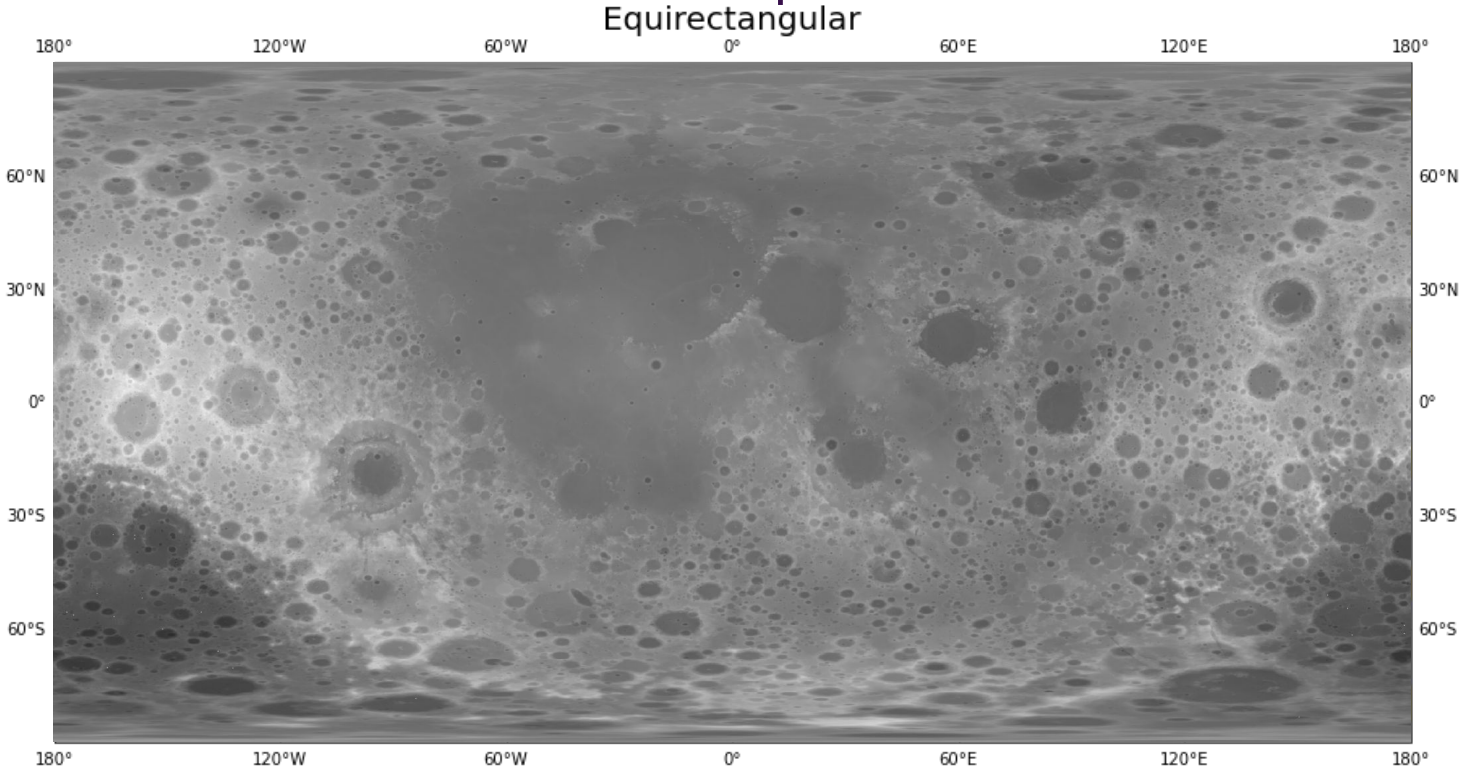
See also ESRI (Winter School GitHub repo)

Examples

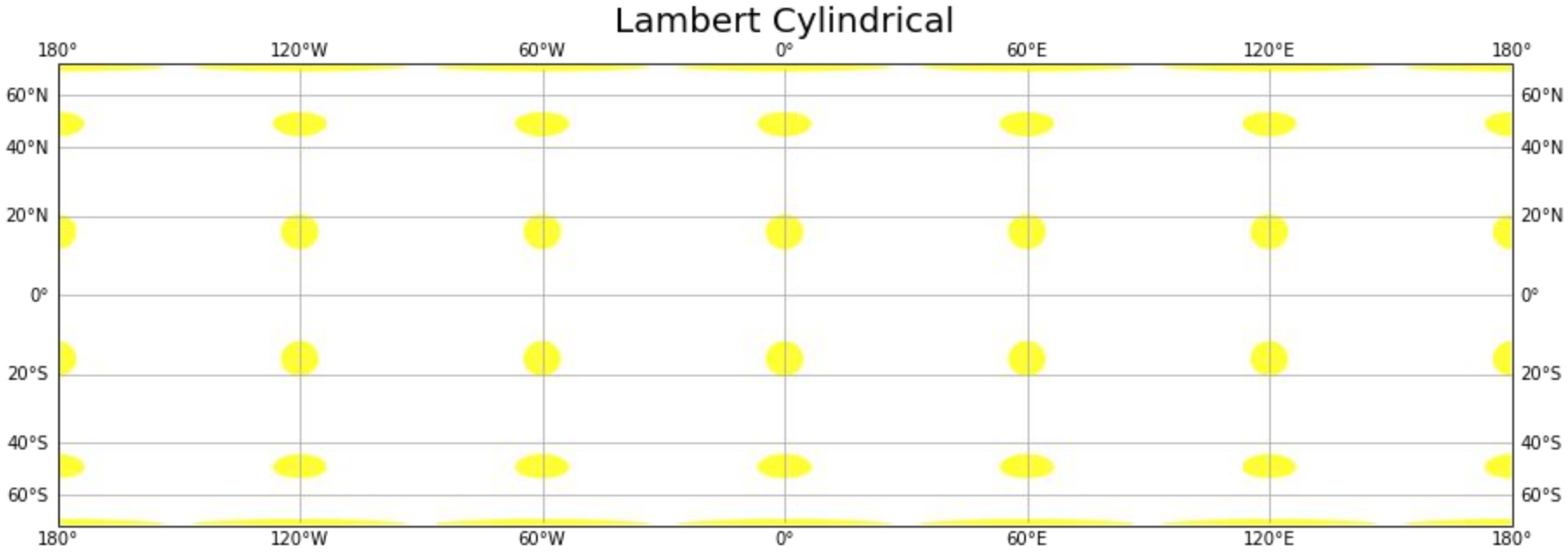


Source: Produced with Cartopy

Examples

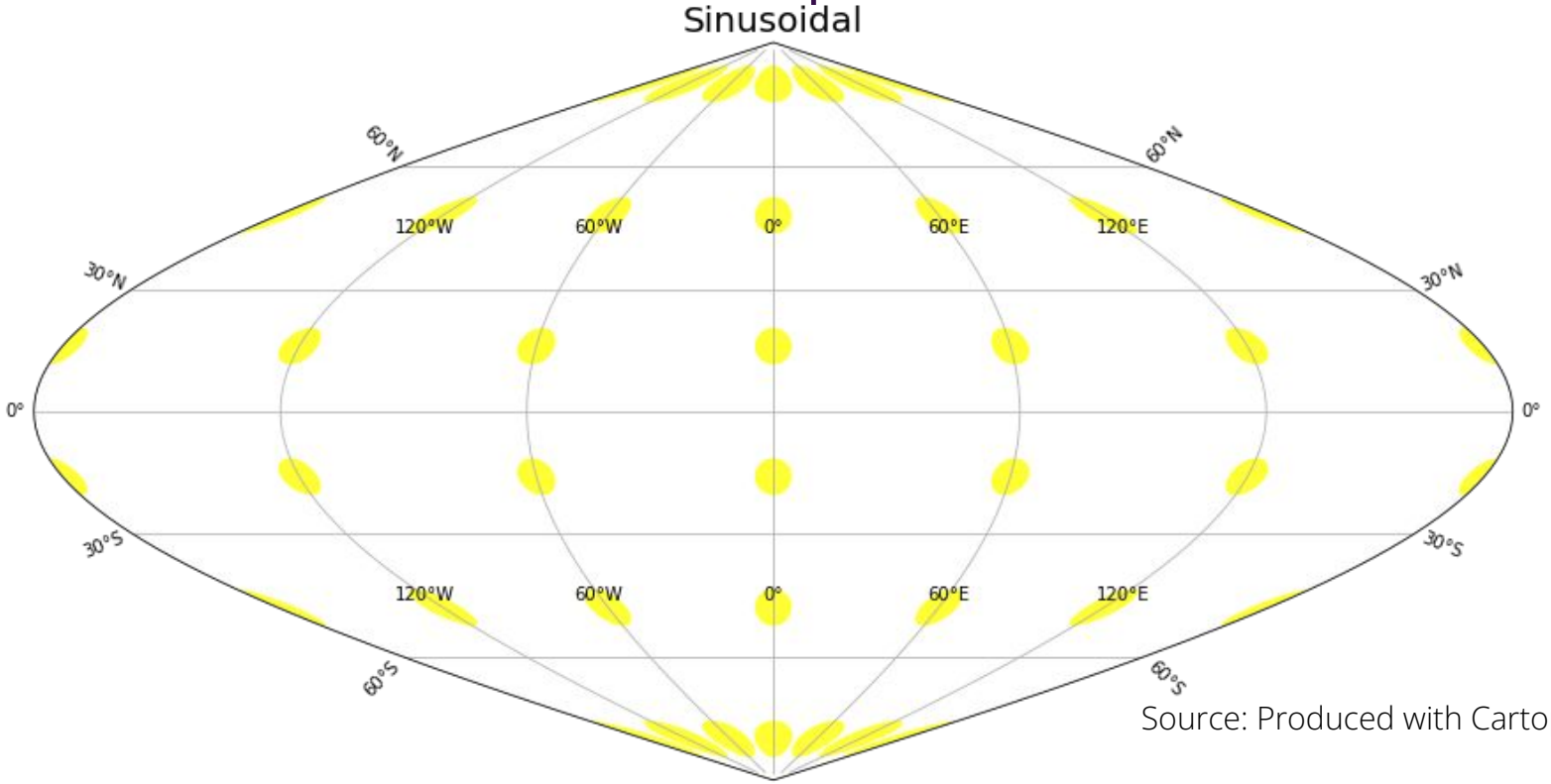


Examples



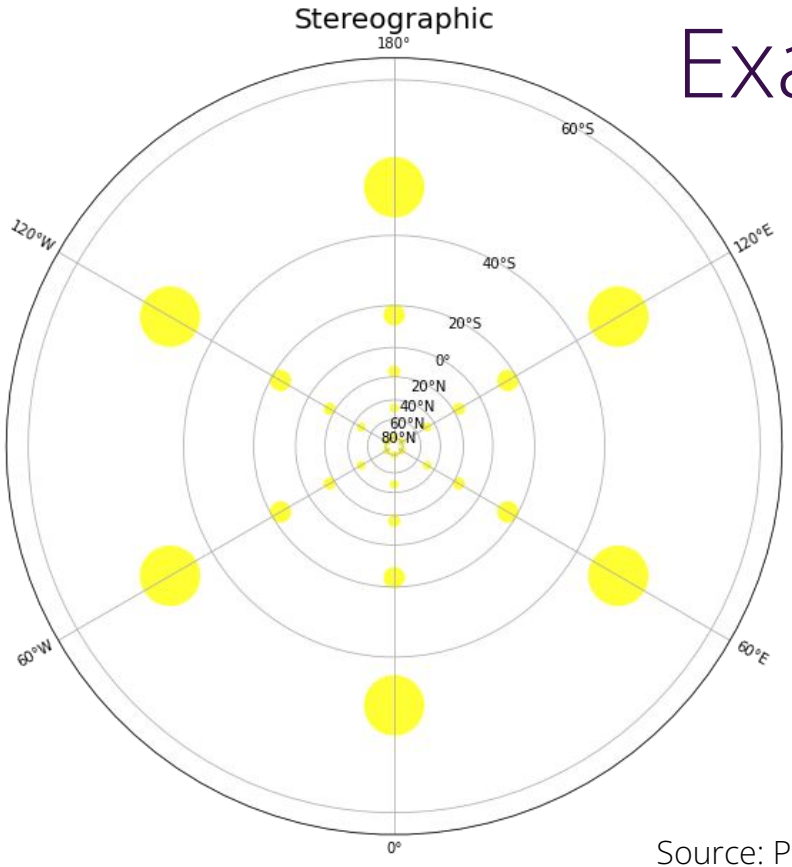
Source: Produced with Cartopy

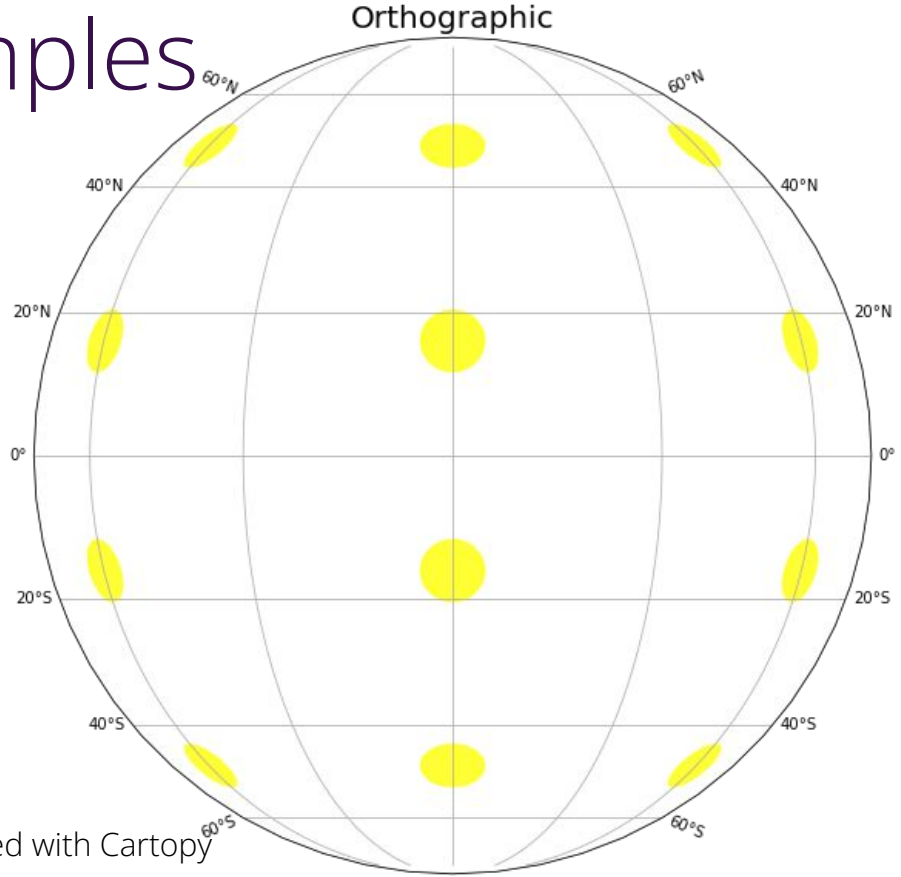
Examples



Source: Produced with Cartopy

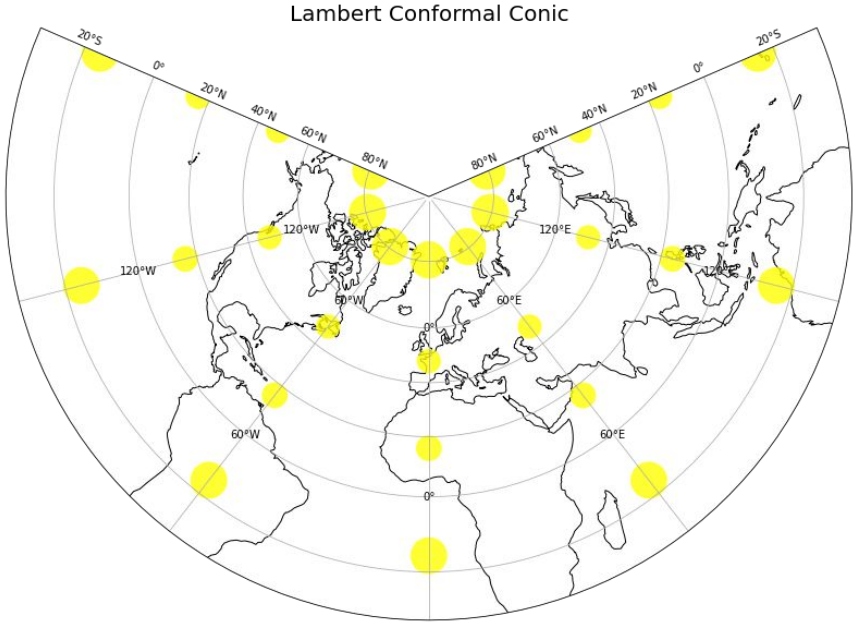
Examples

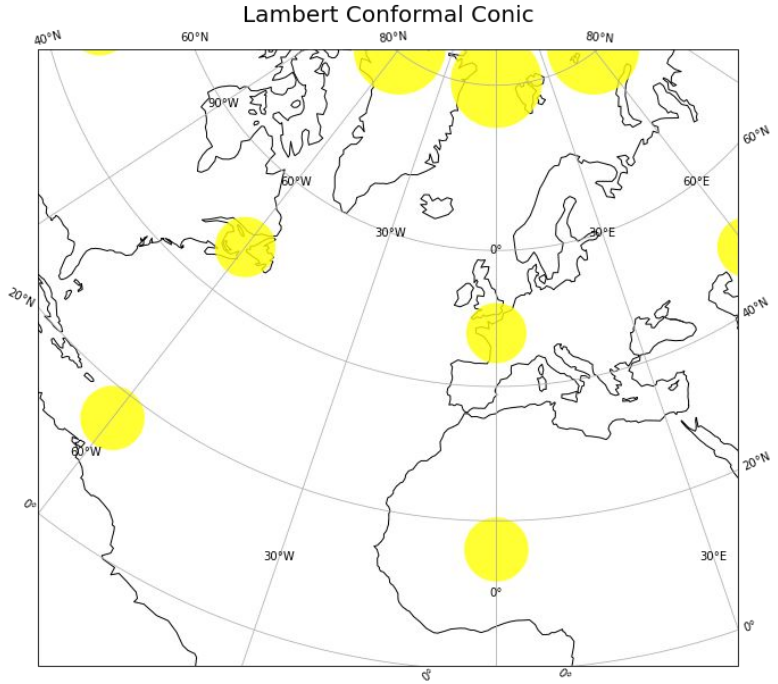




Source: Produced with Cartopy

Examples





Source: Produced with Cartopy

Choosing projections

Region mapped

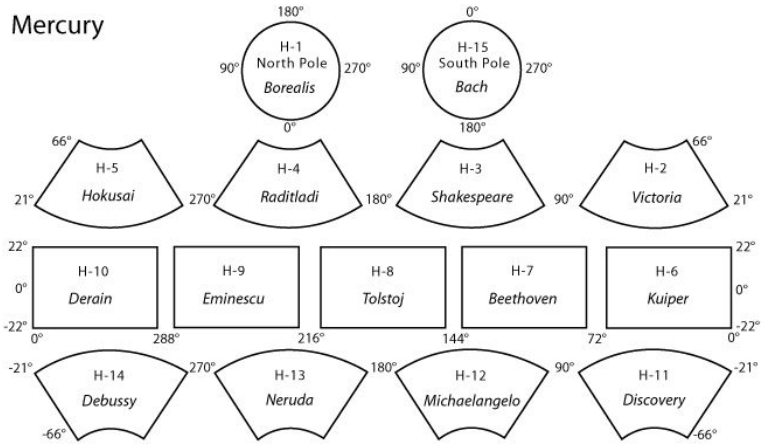
1. World (Earth should be treated as a sphere)
   - A. Conformal (gross area distortion)
     - (1) Constant scale along Equator
       - Mercator
     - (2) Constant scale along meridian
       - Transverse Mercator
     - (3) Constant scale along oblique great circle
       - Oblique Mercator
     - (4) Entire Earth shown
       - Lagrange
       - August
       - Eisenlohr
   - B. Equal-Area
     - (1) Standard without interruption
       - Hammer
       - Mollweide
       - Eckert IV or VI
       - McBryde or McBryde-Thomas variations
       - Boggs Eumorphic
       - Sinusoidal
       - misc. pseudocylindricals
     - (2) Interrupted for land or ocean
       - any of above except Hammer
       - Goode Homolosine
     - (3) Oblique aspect to group continents
       - Briesemeister
       - Oblique Mollweide
   - C. Equidistant
     - (1) Centered on pole
       - Polar Azimuthal Equidistant
     - (2) Centered on a city
       - Oblique Azimuthal Equidistant
   - D. Straight rhumb lines
     - Mercator
   - E. Compromise distortion
     - Miller Cylindrical
     - Robinson

2. Hemisphere (Earth should be treated as a sphere)
   - A. Conformal
     - Stereographic (any aspect)
   - B. Equal-Area
     - Lambert Azimuthal Equal-Area (any aspect)
   - C. Equidistant
     - Azimuthal Equidistant (any aspect)
   - D. Global look
     - Orthographic (any aspect)

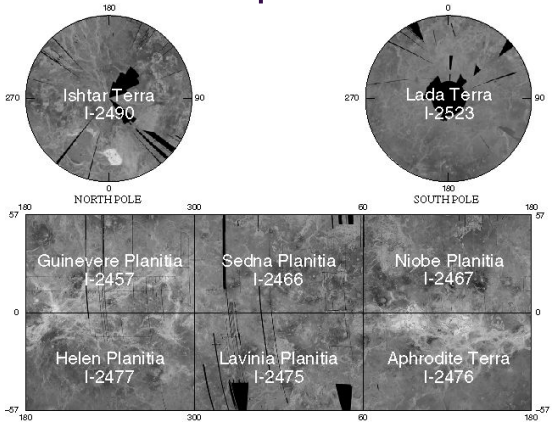
3. Continent, ocean, or smaller region (Earth should be treated as a sphere for larger continents and oceans and as an ellipsoid for smaller regions, especially at a larger scale)
   - A. Predominant east-west extent
     - (1) Along Equator
       - Conformal: Mercator
       - Equal-Area: Cylindrical Equal-Area
     - (2) Away from Equator
       - Conformal: Lambert Conformal Conic
       - Equal-Area: Albers Equal-Area Conic
   - B. Predominant north-south extent
     - Conformal: Transverse Mercator
     - Equal-Area: Transverse Cylindrical Equal-Area
   - C. Predominant oblique extent (for example: North America, South America, Atlantic Ocean)
     - Conformal: Oblique Mercator
     - Equal-Area: Oblique Cylindrical Equal-Area
   - D. Equal extent in all directions (for example: Europe, Africa, Asia, Australia, Antarctica, Pacific Ocean, Indian Ocean, Arctic Ocean, Antarctic Ocean)
     - (1) Center at pole
       - Conformal: Polar Stereographic
       - Equal-Area: Polar Lambert Azimuthal Equal-Area
     - (2) Center along Equator
       - Conformal: Equatorial Stereographic
       - Equal-Area: Equatorial Lambert Azimuthal Equal-Area
     - (3) Center away from pole or Equator
       - Conformal: Oblique Stereographic
       - Equal-Area: Oblique Lambert Azimuthal Equal-Area
   - E. Straight rhumb lines (principally for oceans)
     - Mercator
   - F. Straight great-circle routes
     - Gnomonic (for less than hemisphere)
   - G. Correct scale along meridians
     - (1) Center at pole
       - Polar Azimuthal Equidistant
     - (2) Center along Equator
       - Plate Carrée (Equidistant Cylindrical)
     - (3) Center away from pole or Equator
       - Equidistant Conic

Source: Snyder (1987)

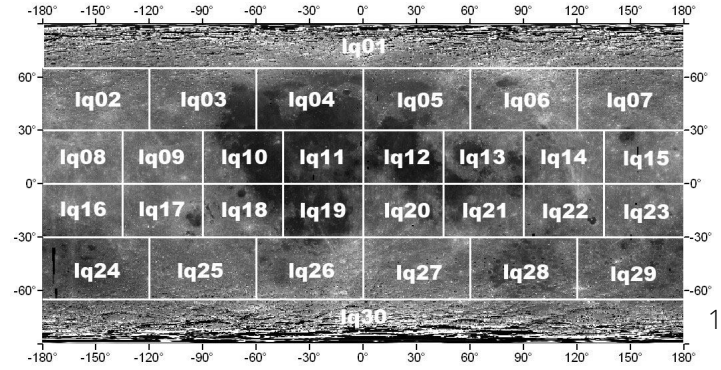
Examples for planetary (regional) maps



1:5 Million

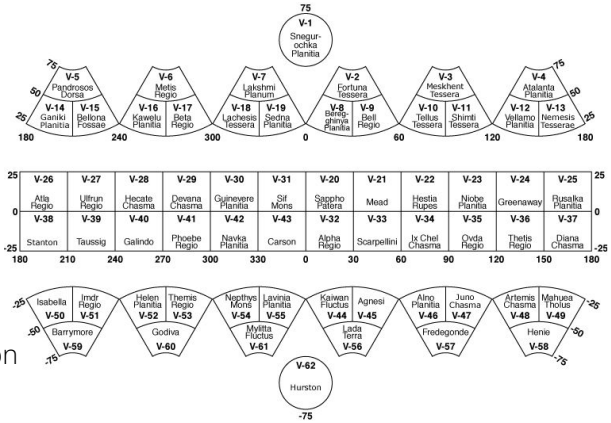


1:10 Million



1:2.5 Million

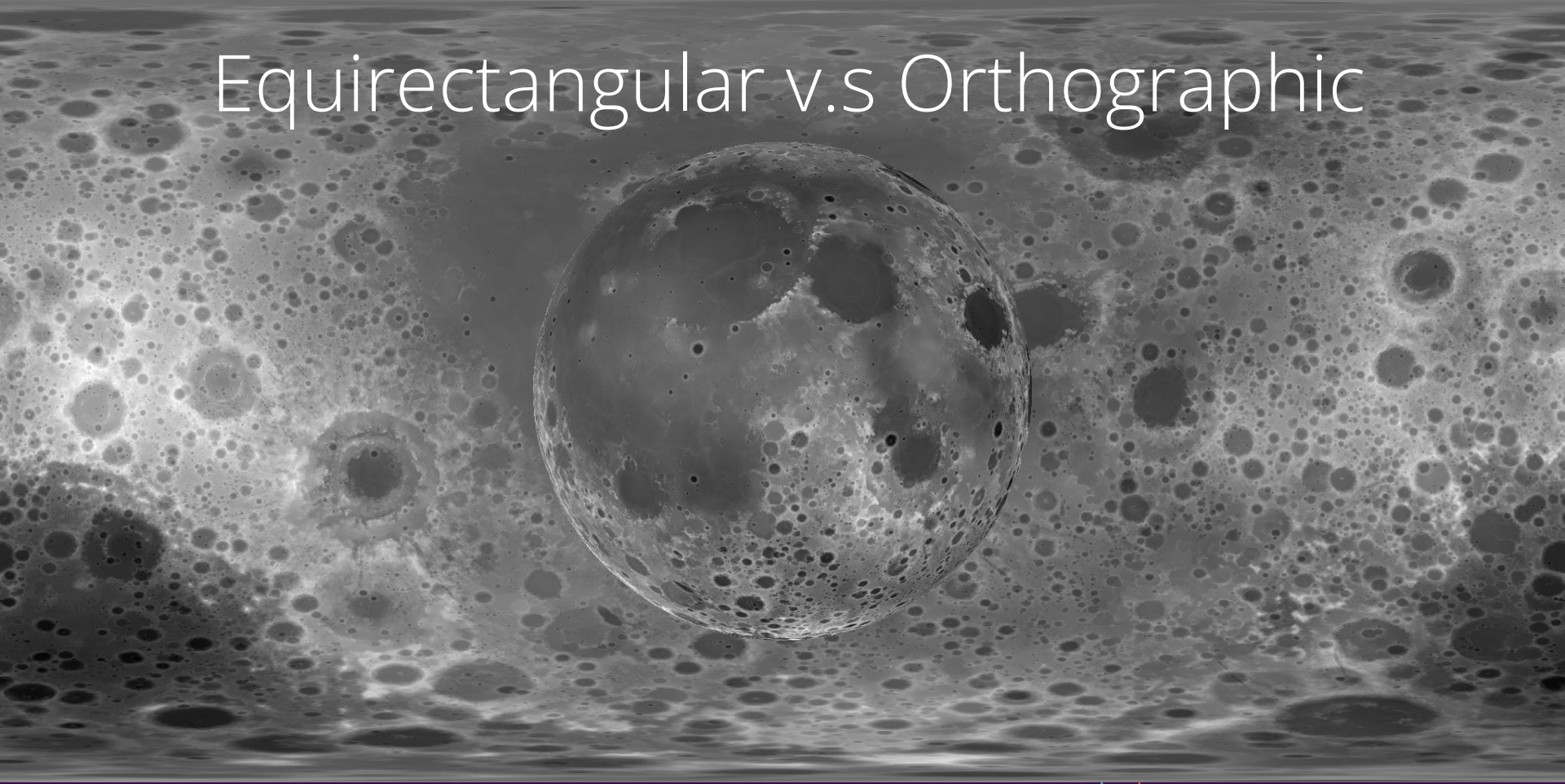
Source: USGS



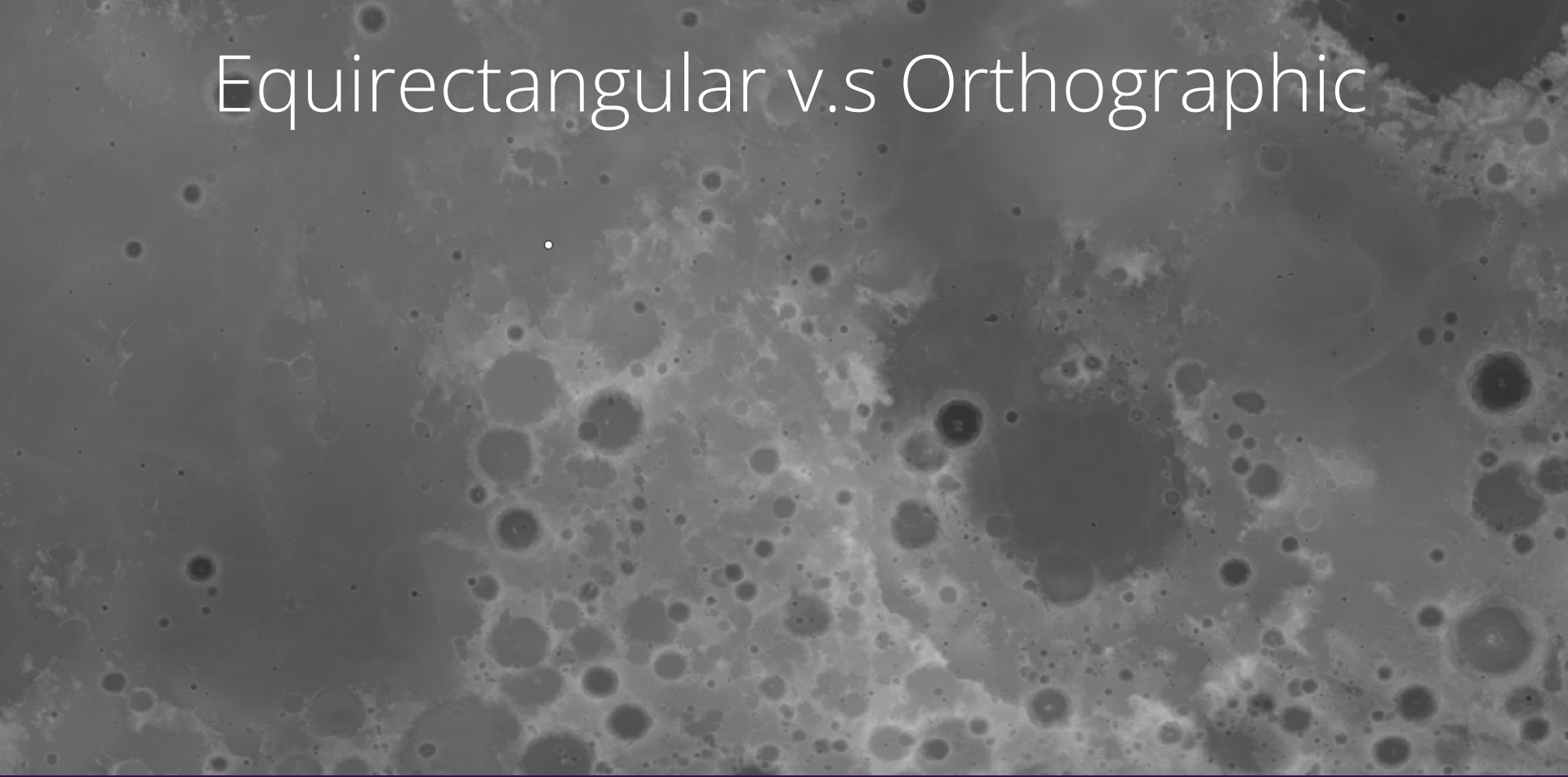
1:5 Million

The Moon: Equirectangular

Equirectangular v.s Orthographic

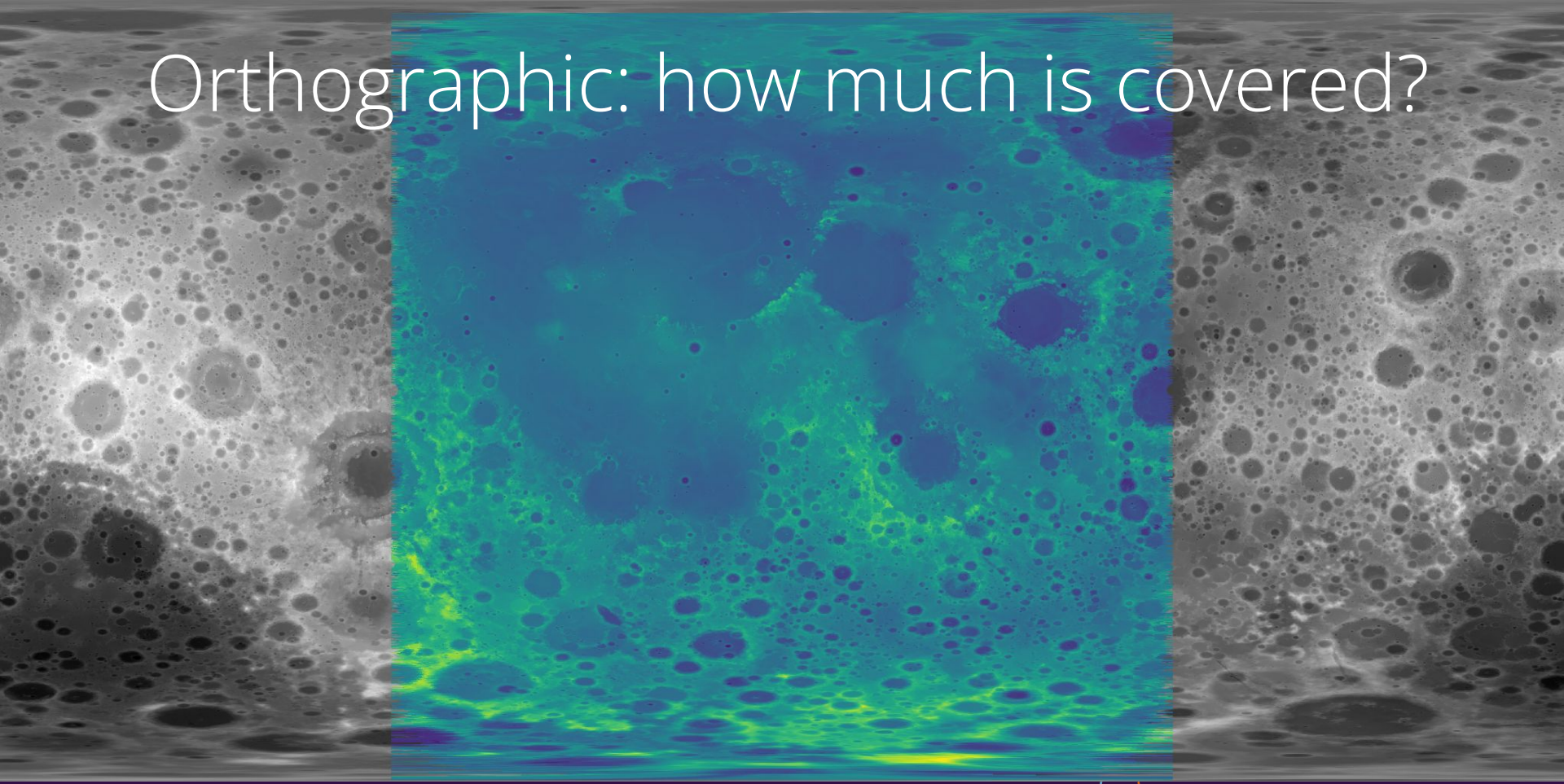


Equirectangular v.s Orthographic

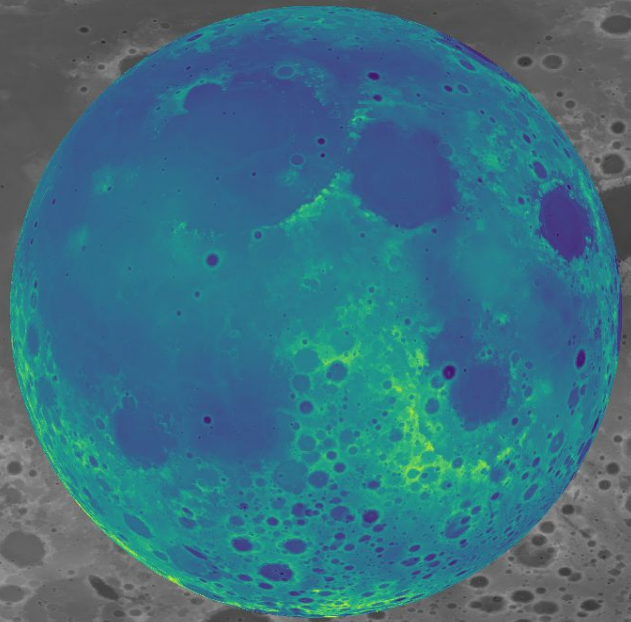


Equirectangular v.s Orthographic

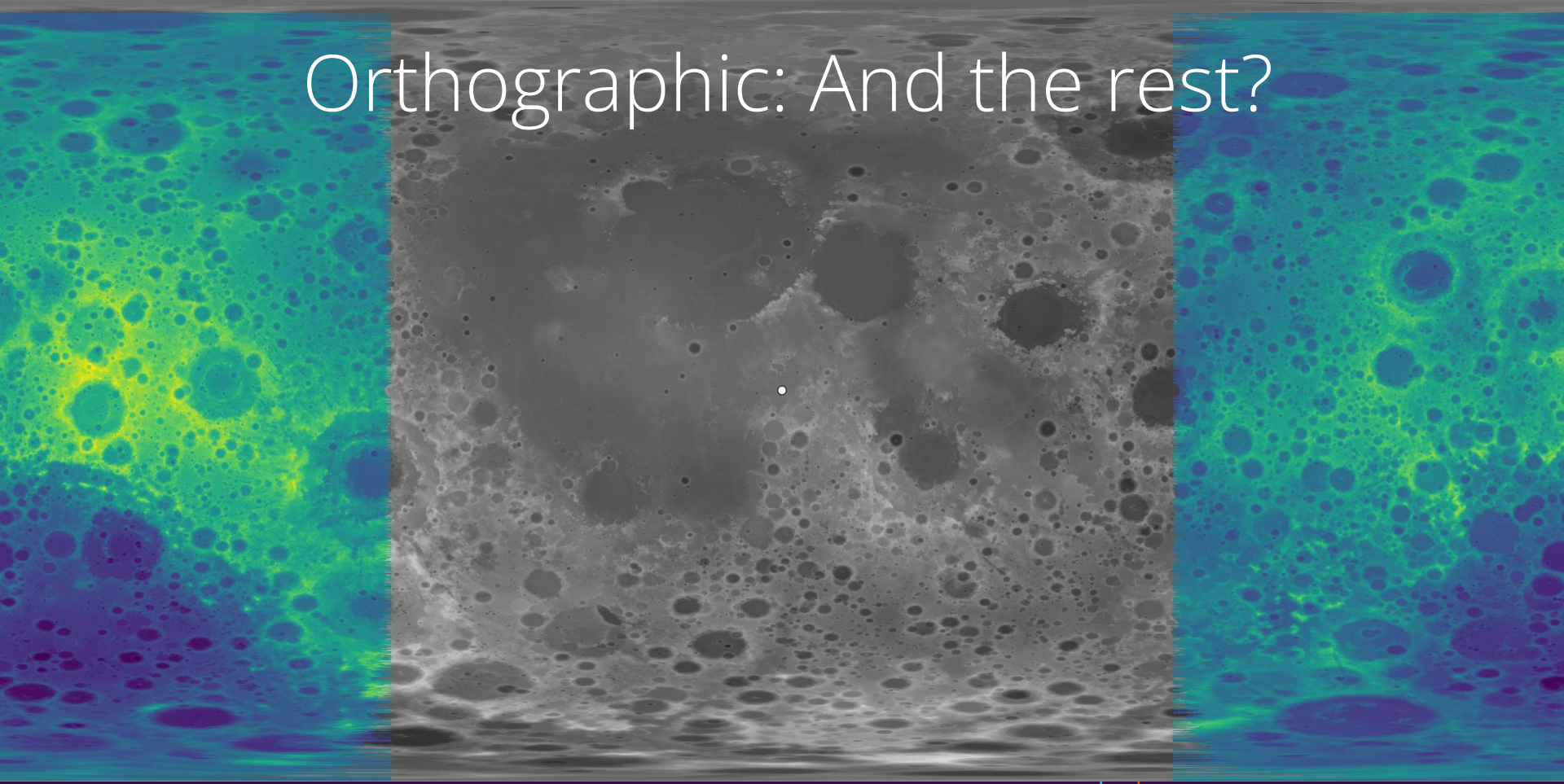
Orthographic: how much is covered?

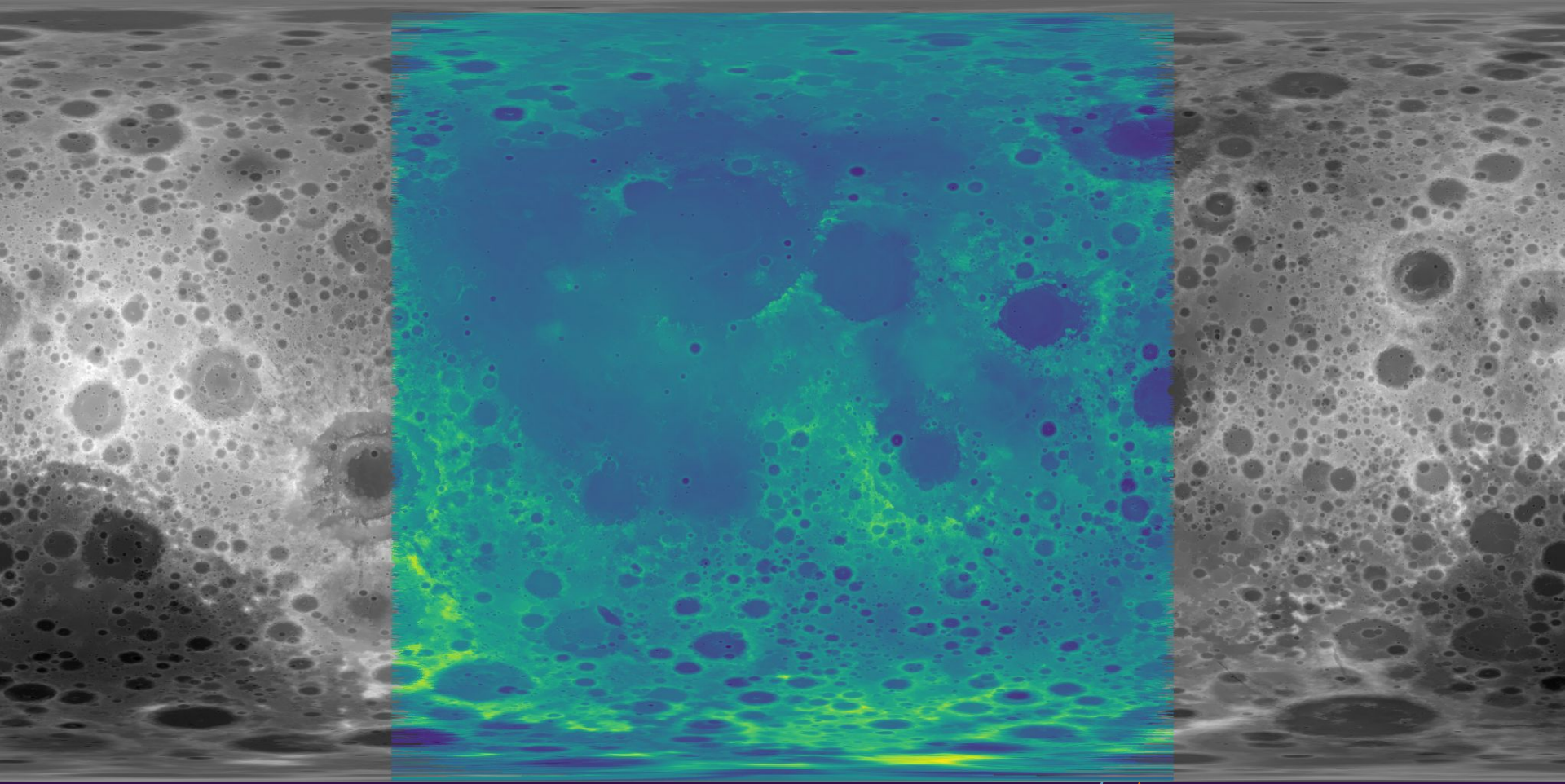


Orthographic: how much is covered?

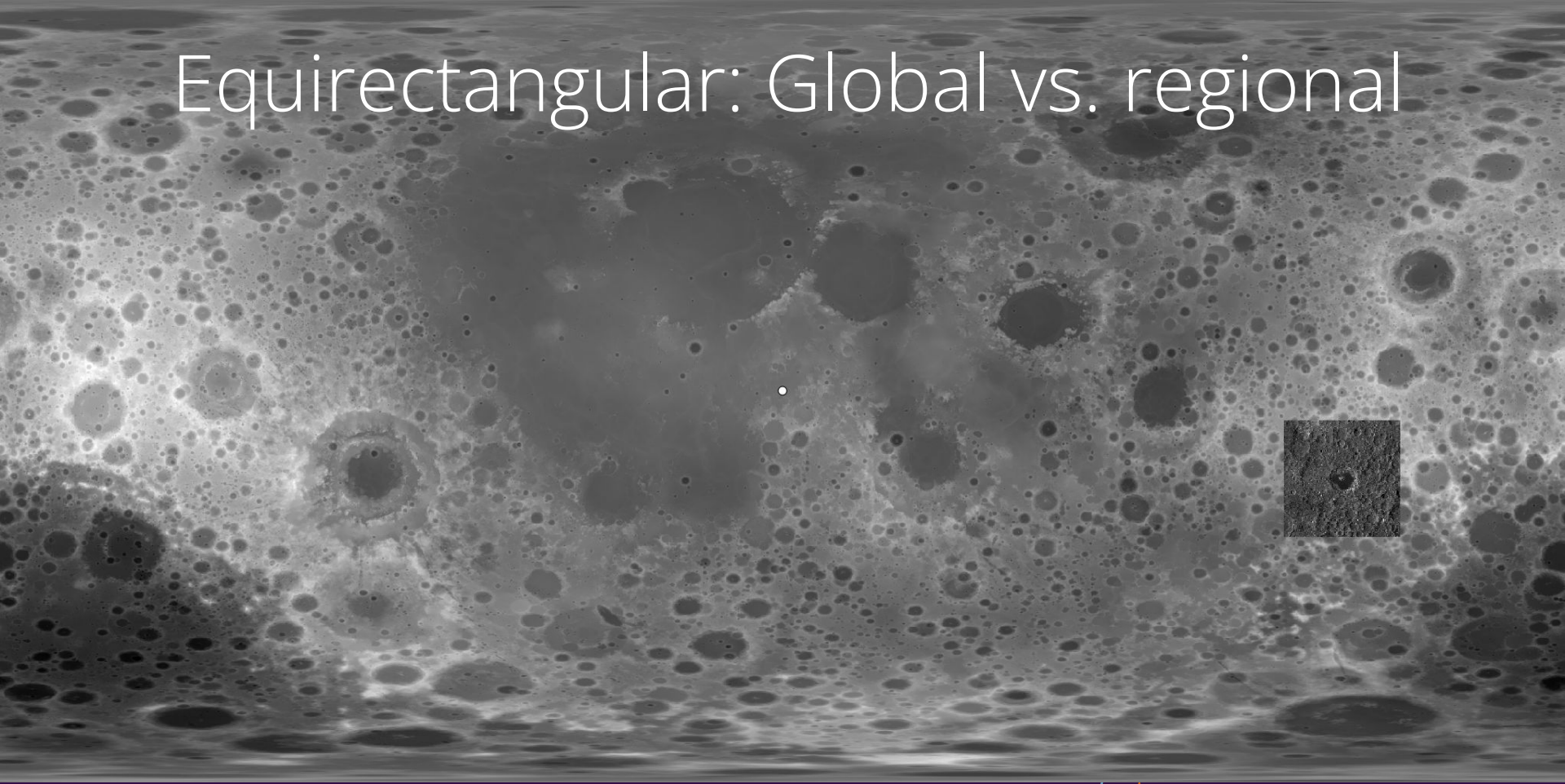


Orthographic: And the rest?

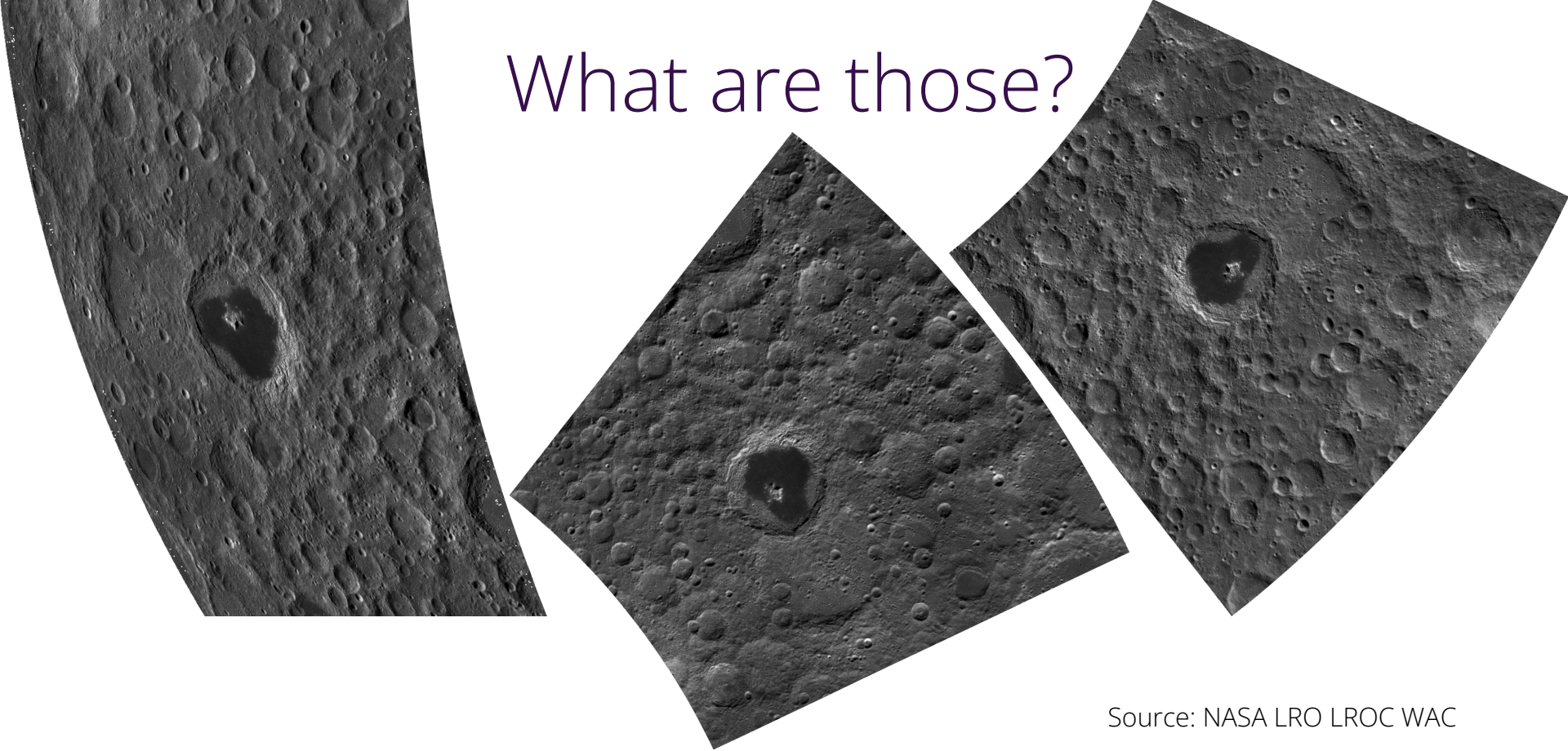




Equirectangular: Global vs. regional

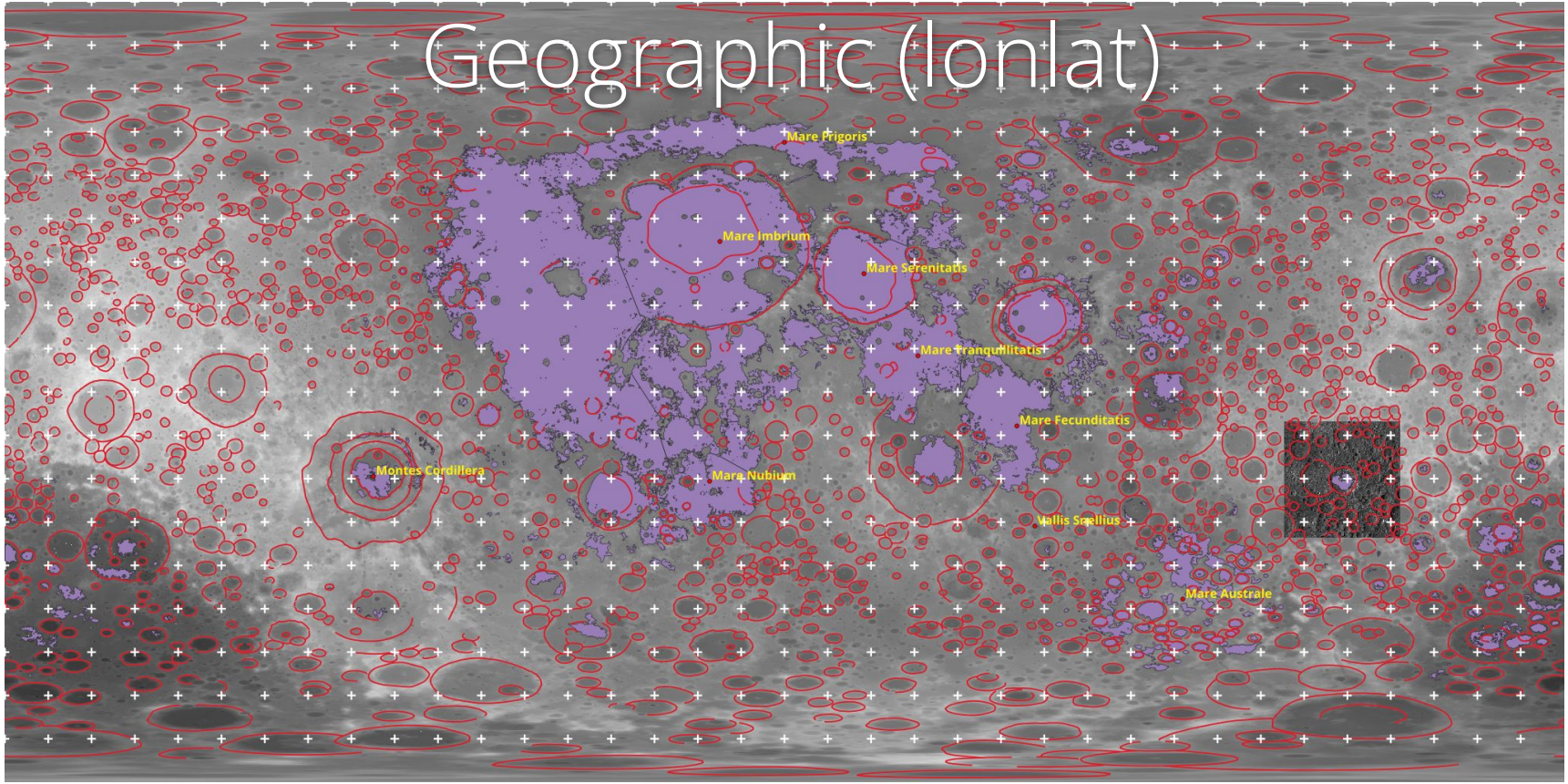


What are those?



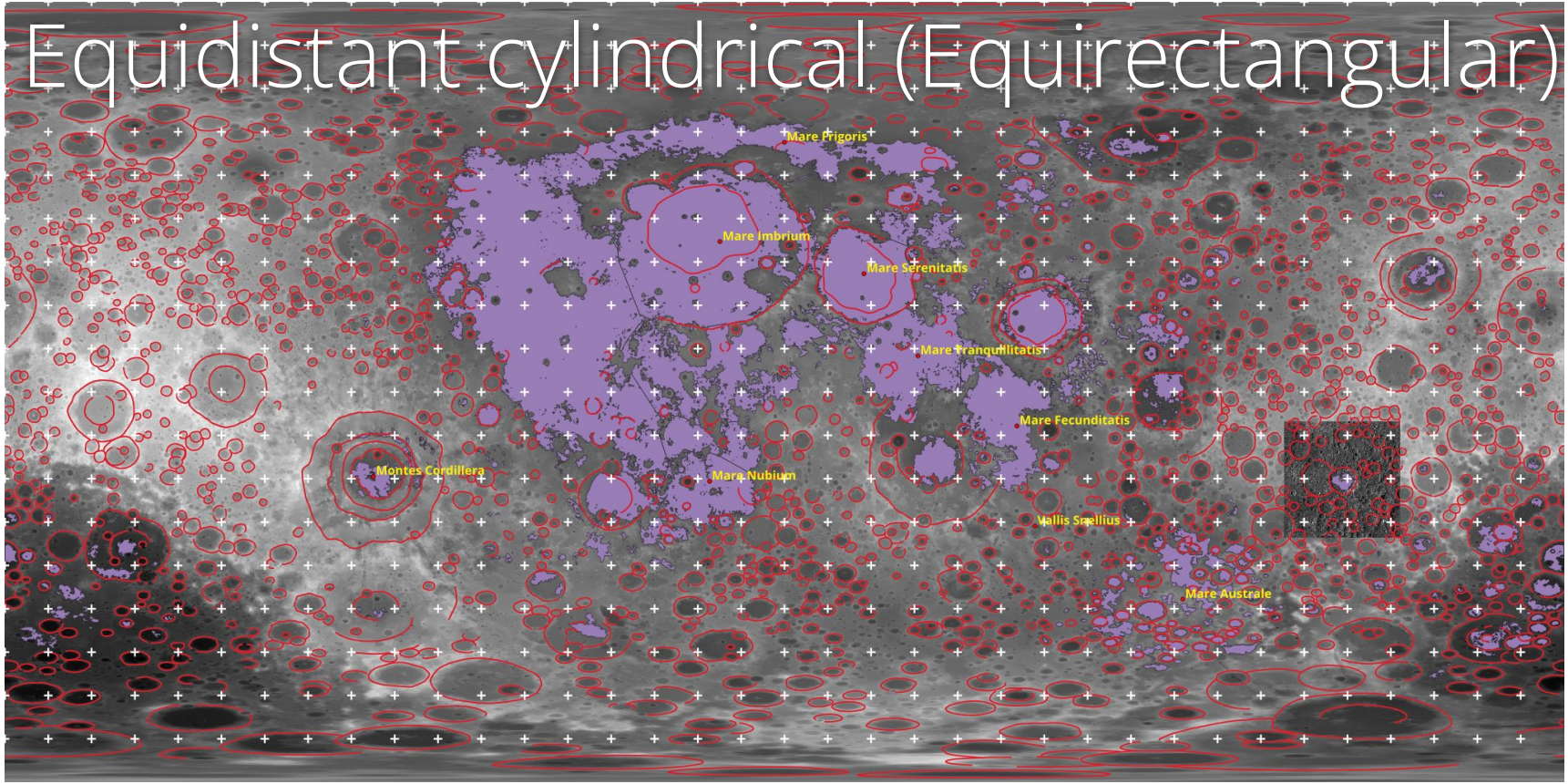
Source: NASA LRO LROC WAC

Geographic (lonlat)



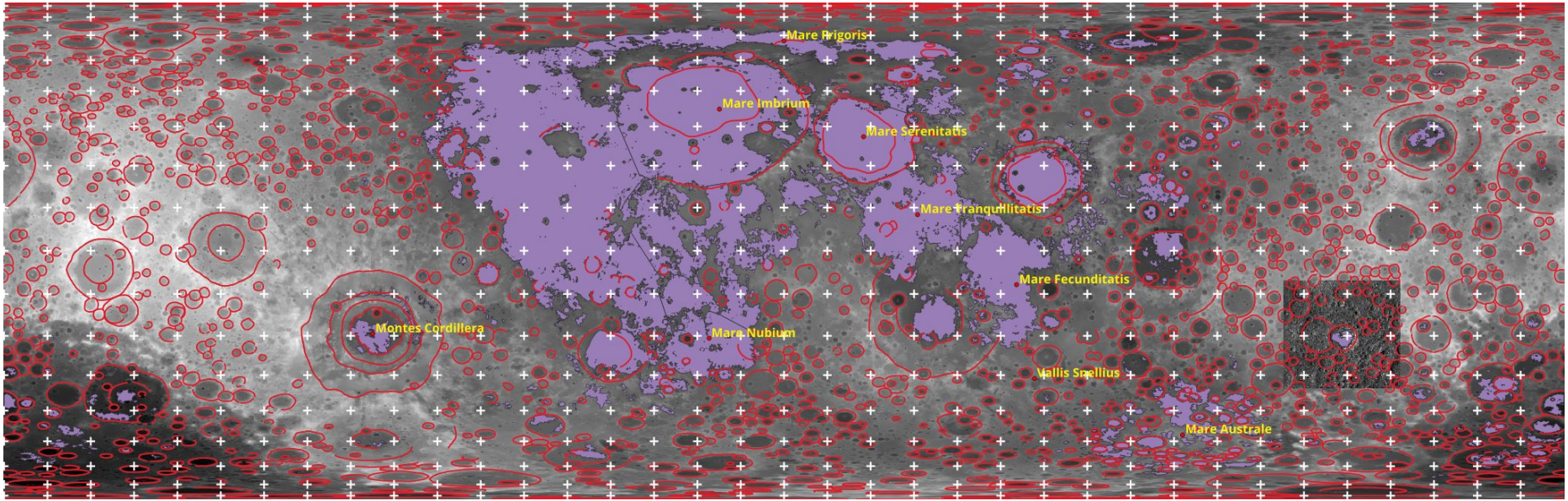
Source: NASA LRO LOLA, USGS, ASU (see final slide on sources)

Equidistant cylindrical (Equirectangular)



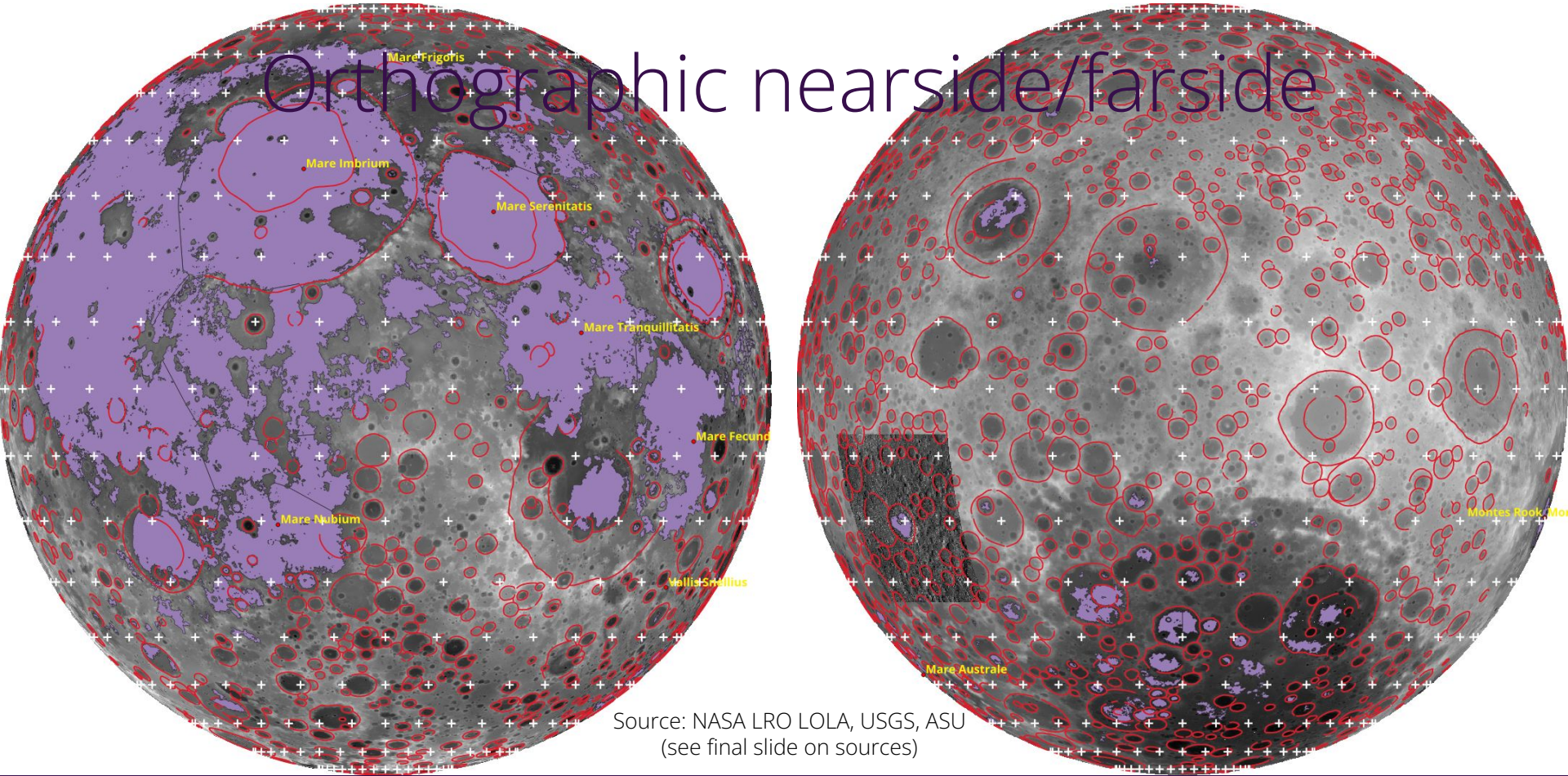
Source: NASA LRO LOLA, USGS, ASU (see final slide on sources)

Equal-area cylindrical



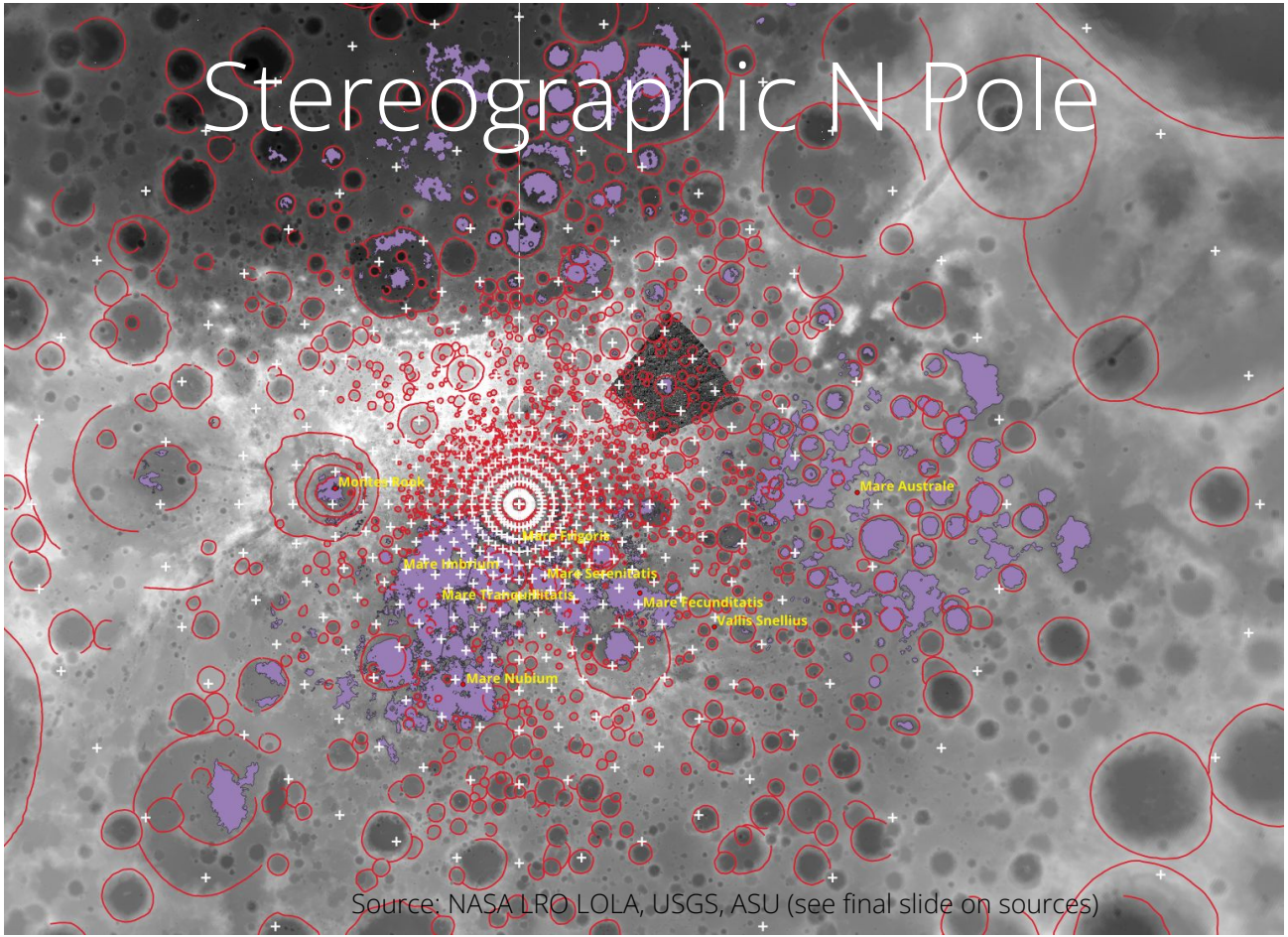
Source: NASA LRO LOLA, USGS, ASU (see final slide on sources)

Orthographic nearside/farside



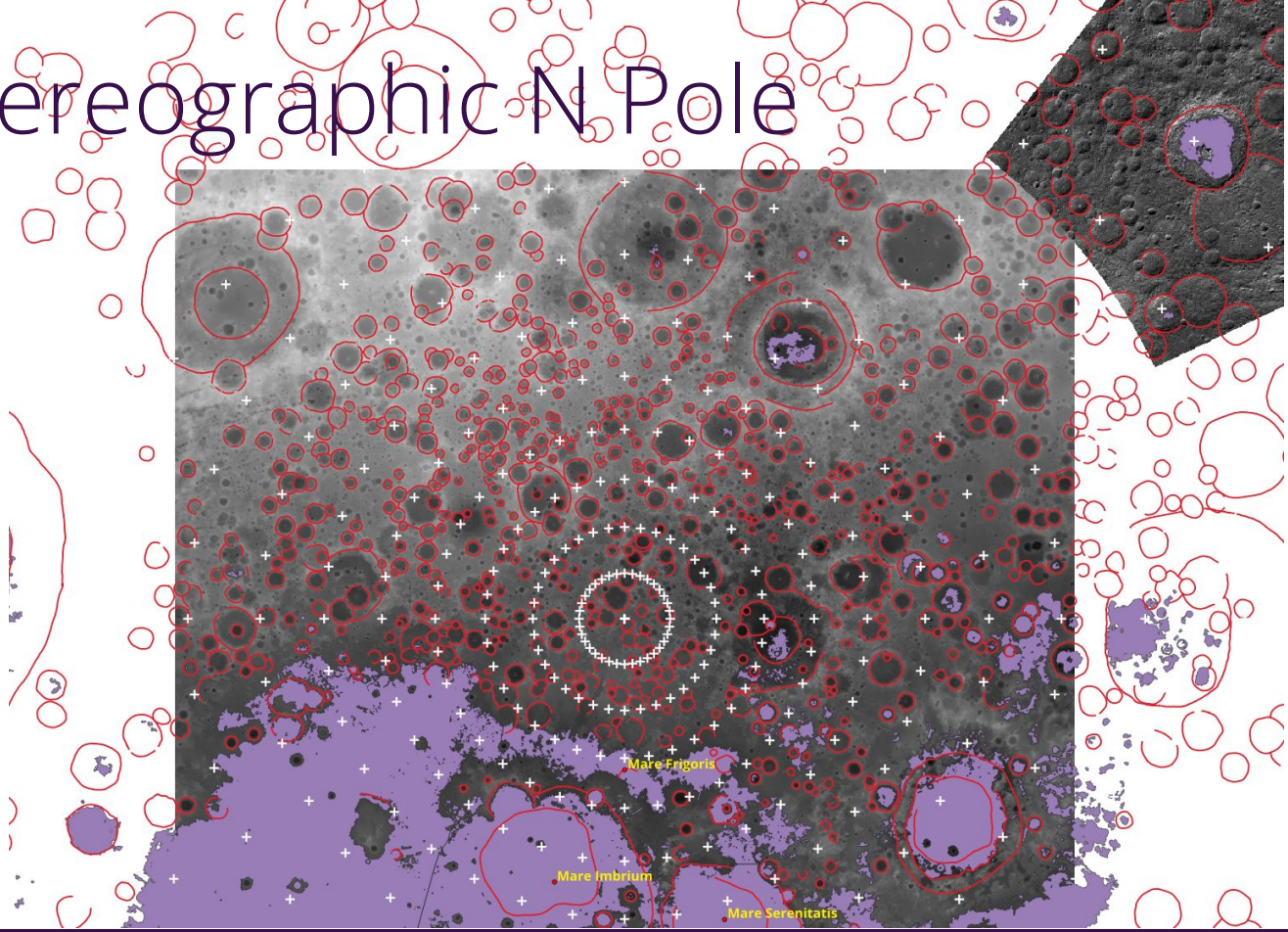
Source: NASA LRO LOLA, USGS, ASU
(see final slide on sources)

Stereographic N Pole



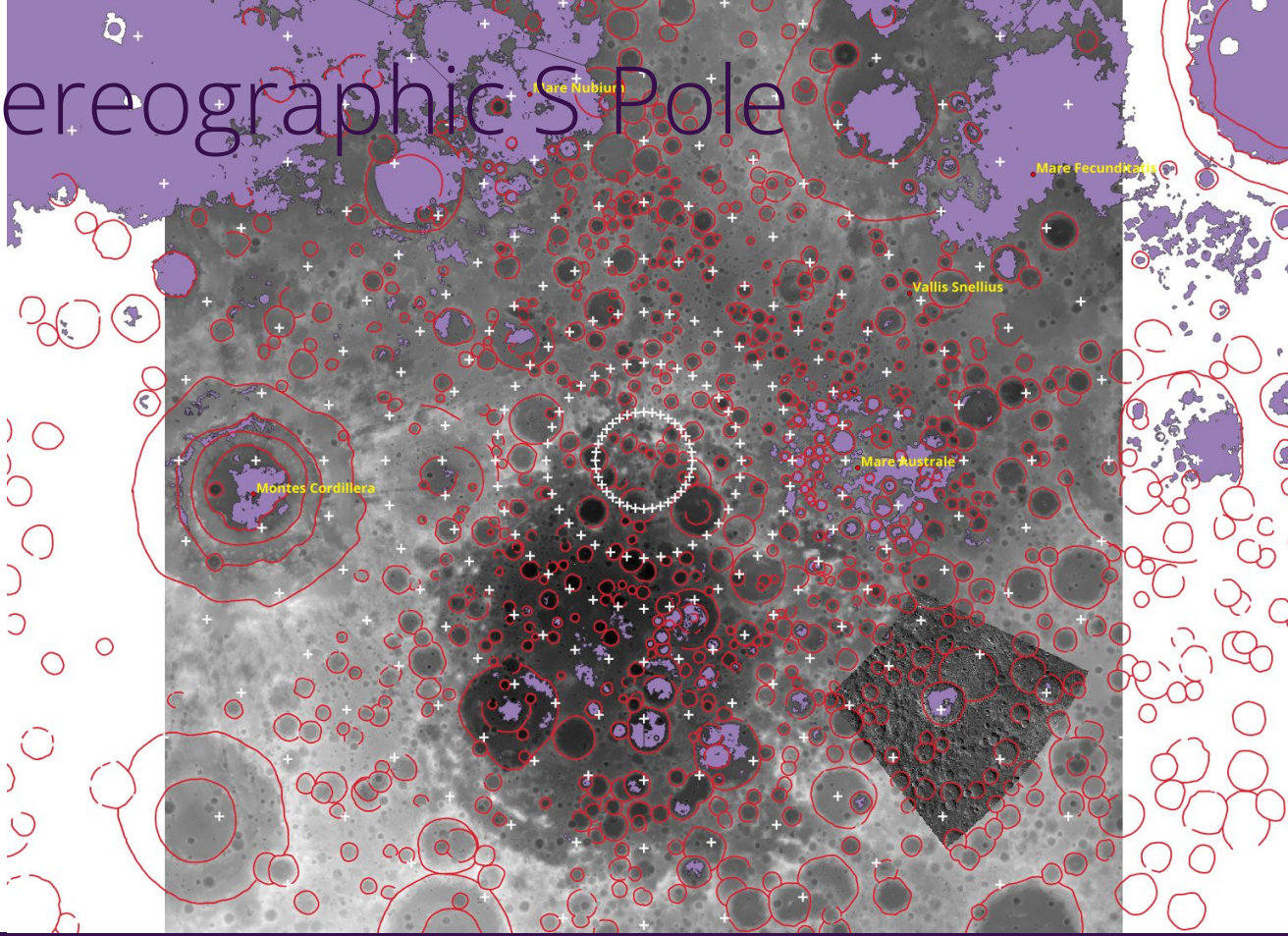
Source: NASA LRO LOLA, USGS, ASU (see final slide on sources)

Stereographic N Pole



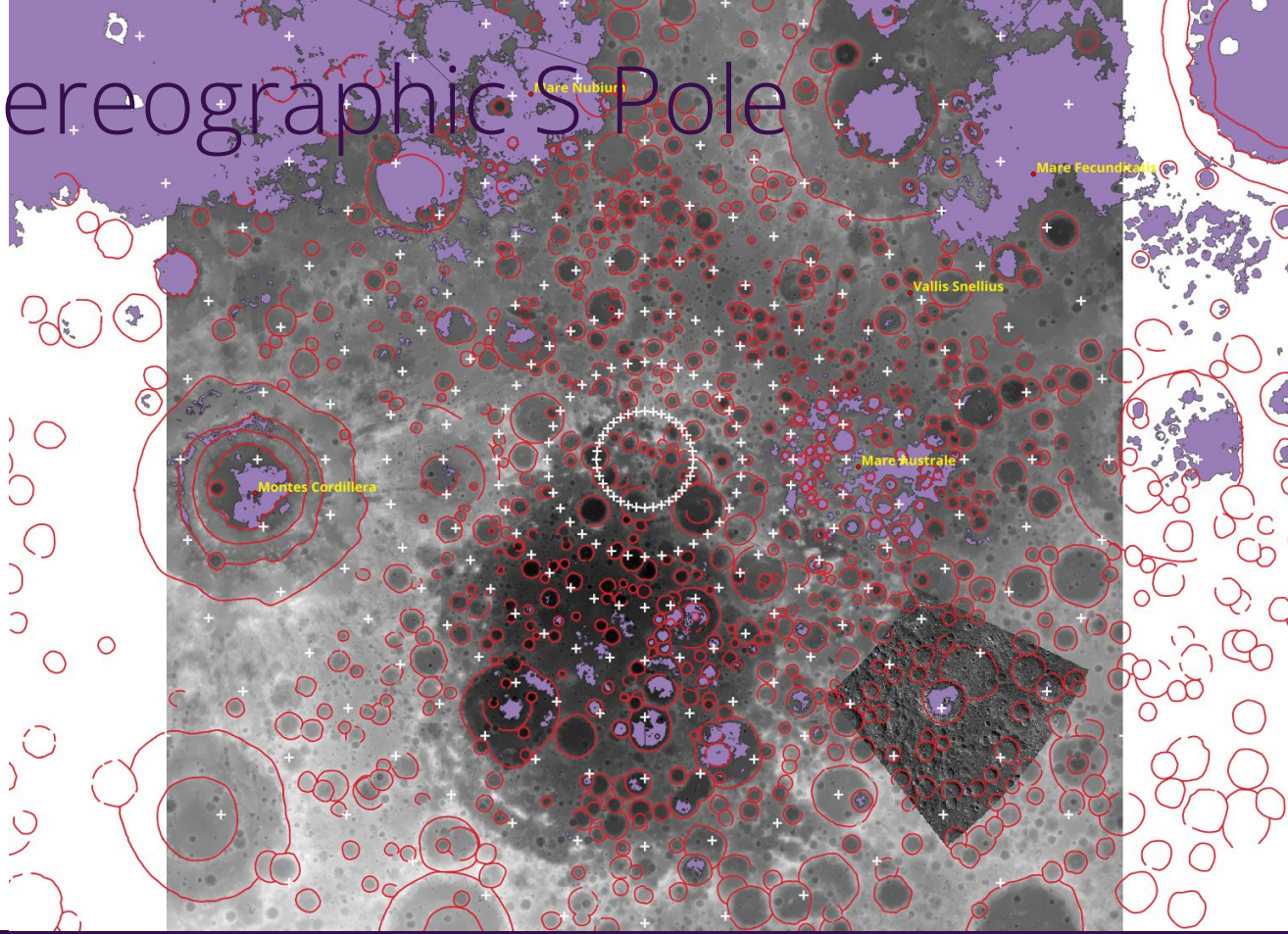
Source: NASA LRO LOLA, USGS, ASU (see final slide on sources)

Stereographic S Pole



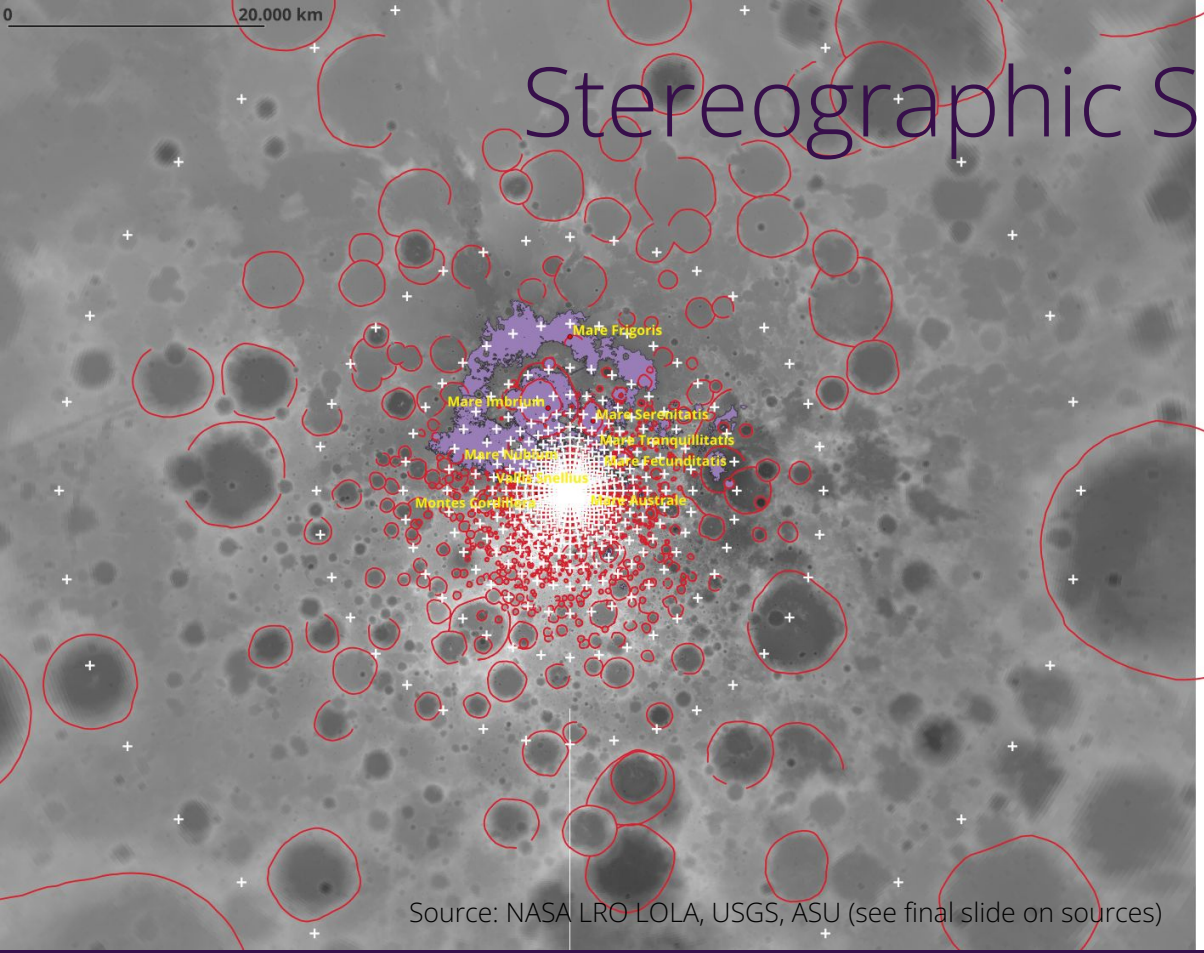
Source: NASA LRO LOLA, USGS, ASU
(see final slide on sources)

Stereographic S Pole

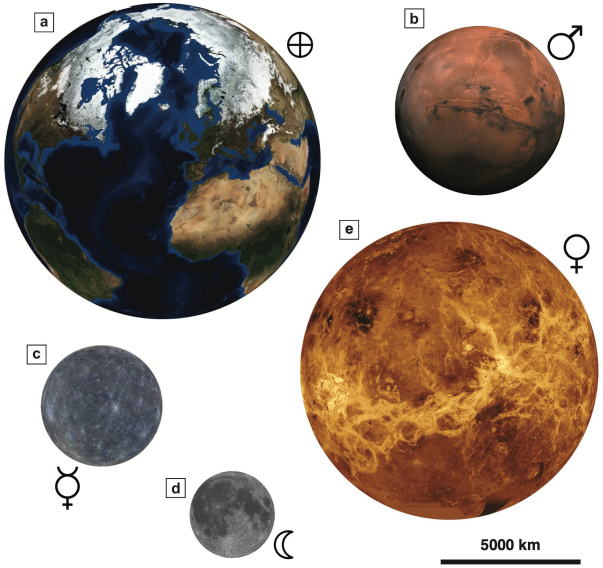


Source: NASA LRO LOLA, USGS, ASU
(see final slide on sources)

Stereographic S Pole

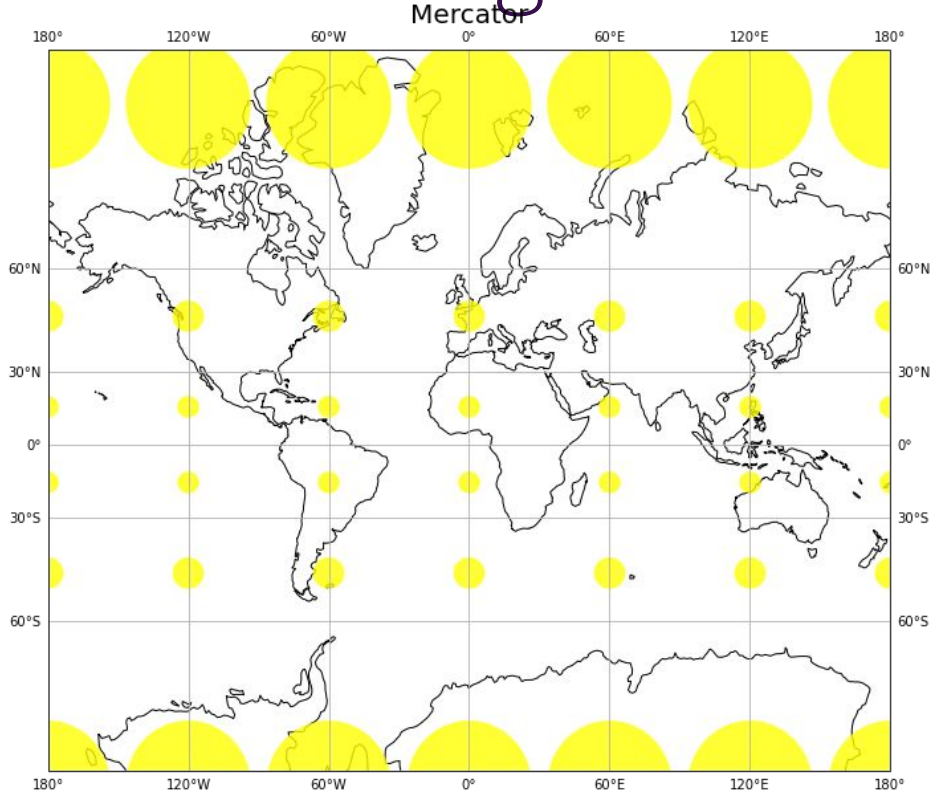


Source: NASA LRO LOLA, USGS, ASU (see final slide on sources)



Source: Rossi and van Gasselt (2018)

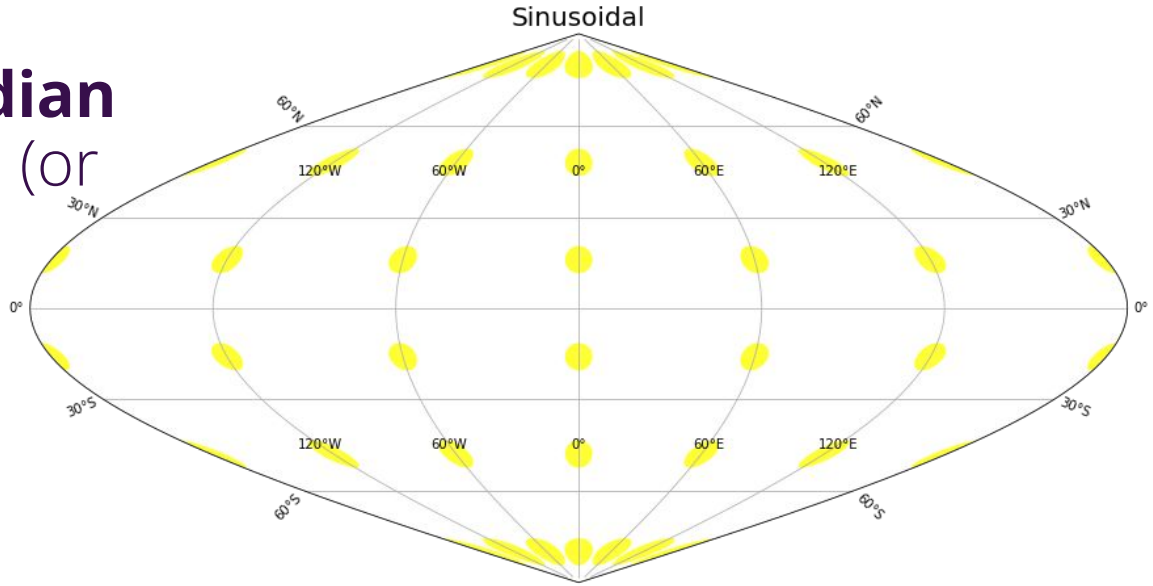
Similar to Big Greenland (@Mercator)…



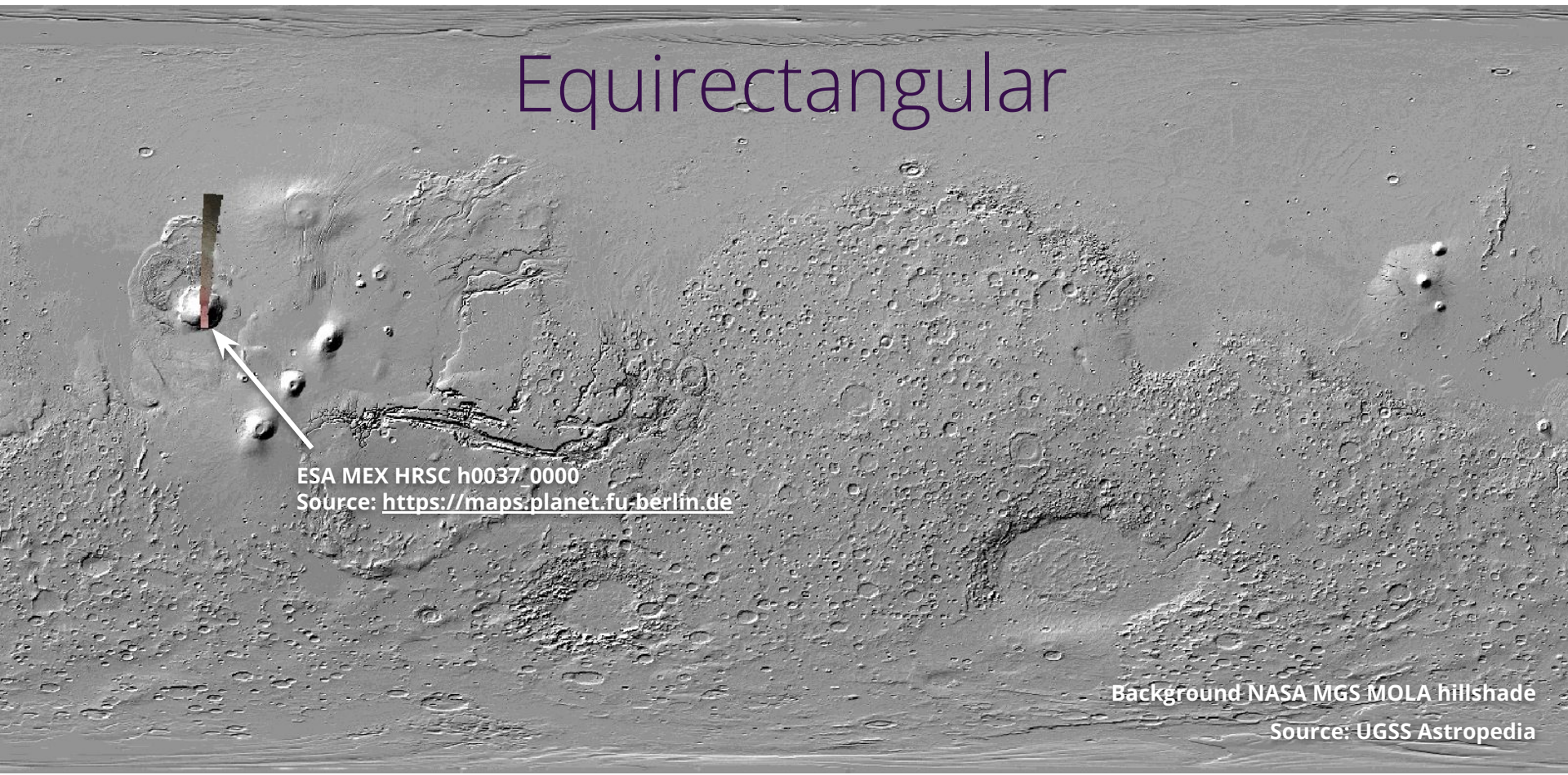
Source: Produced with Cartopy

1 sec. Back to Sinusoidal

- **Little deformation along central meridian**
- Depend on your map (or data granule) aspect ratio…
- E.g. long ~N-S data strips, such as **HRSC** (more later) come projected, as **single granules**, in Sinusoidal



Equirectangular



ESA MEX HRSC h0037_0000
Source: https://maps.planet.fu-berlin.de

Background NASA MGS MOLA hillshade
Source: UGSS Astropedia

Sinusoidal clon=0

Sinusoidal clon=-133 (227)

Intro to GIS & planetary mapping

Van Gasselt (2015) Planetary GIS: An introduction - ESA Planetary GIS Workshop https://www.youtube.com/watch?v=hOiJWqDSP_Q

Hare (2015) Why cartography Matters for GIS - ESA Planetary GIS Workshop https://www.youtube.com/watch?v=b9Wqo2KSUNA

Relevant references

Georgiadou, P.Y., Knippers, R.A., Kraak, M.J., Sun, Y., Weir, M.J.C. and van Westen, C.J. Principles of geographic information systems (Chapter 4.2 on spatial referencing), 2nd edition, ITC Educational Textbook, ITC, Enschede, 2001. Available online at https://webapps.itc.utwente.nl/librarywww/papers_2009/general/principlesgis.pdf

Hare, T.M., Skinner, J.A., Kirk, R.L. (2018). Cartography Tools. In: Rossi, A., van Gasselt, S. (eds) Planetary Geology. Springer Praxis Books(). Springer, Cham. https://doi.org/10.1007/978-3-319-65179-8_4

Hargitai, H., Wang, J., Stooke, P.J., Karachevtseva, I., Kereszturi, A., Gede, M. (2017). Map Projections in Planetary Cartography. In: Lapaine, M., Usery, E. (eds) Choosing a Map Projection. Lecture Notes in Geoinformation and Cartography(). Springer, Cham. https://doi.org/10.1007/978-3-319-51835-0_7

Kessler, F. C., & Battersby, S. E. (2019). Working with Map Projections. https://doi.org/10.1201/9780203731413

Knippers, R., (2009) Geometric aspects of mapping, available online at https://kartoweb.itc.nl/geometrics/index.html

NAIF (2022) An Overview of Reference Frames and Coordinate Systems in the SPICE Context available online at https://naif.jpl.nasa.gov/pub/naif/toolkit_docs/Tutorials/pdf/individual_docs/17_frames_and_coordinate_systems.pdf

Šavrič, B,, Jenny B, Jenny H. (2016) Projection Wizard – An Online Map Projection Selection Tool, The Cartographic Journal, 53:2, 177-185, DOI: 10.1080/00087041.2015.1131938

Snyder, J. P. (1987). Map projections--A working manual (Vol. 1395). US Government Printing Office - https://pubs.er.usgs.gov/publication/pp1395

See also: https://github.com/europlanet-gmap/winter-school-2023/tree/main/crs

Tools and web services

https://projectionwizard.org

USGS Map-a-planet:
https://astrocloud.wr.usgs.gov/index.php?view=map2

USGS POW: https://astrocloud.wr.usgs.gov/index.php?view=pow

http://countrymovers.elte.hu/countrymovers.html

See also
https://github.com/europlanet-gmap/awesome-planetary-geology

Data sources

See: https://github.com/europlanet-gmap/winter-school-2023/tree/main/crs