LARGE-AREA SKY SURVEYS
After obtaining your survey data. . . ?

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Adapted from a slideshow—sorry for the wierd format

Perhaps the most important part of this document is the last two pages! They talk about FITS files and projections, and FITS files and IDL

SOME IMPORTANT DATA SOURCES

You usually want to compare your data with other types of data. A very useful website is
`http://skyview.gsfc.nasa.gov`

It provides instantaneous maps of many types of data. Try the basic interface first. Available maps include:

- gamma ray (EGRET)
- Hard X ray
- Soft X rays (For all-sky: ROSAT .25, .75, 1.5 keV)
- EUV
- UV
- Optical
- IR
- RADIO

with different projections, stretches, grids, coordinate systems.

If you generate an image it will download it as an image or as the corresponding gridded file. Often this isn't good enough. For most data sources, skyview provides access to the original, unadulterated data if you go to the advanced interface. Click on

```
SURVEY INFORMATION
```

which lists the source web pages.

You should regard `skyview` **as a generic data provider. In some cases it's better to use original data websites or specialized pages. In particular. . .**

FOR DIFFUSE ISM related data I recommend Doug Finkbeiner's page
`www.skymaps.info`

which is best for

- **Galactic extinction**
- **CO**
- **dust emission at IR and microwave**
- **Galactic diffuse synchrotron emisssion**
- **Galactic diffuse Halpha**

For the 21-cm line, use the 0.6 deg resolution of northern sky
`LDS survey (Leiden-Dwingeloo survey)`

by Dap Hartmann and Butler Burton. It's original source is a CD from Cambridge University Press, but there are many digital copies floating around.

This is now superseded by the all-sky
`Leiden/Argentine/Bonn (LAB) survey`

by Kalberla et al (Google "lab survey"). Copies of entire catalog reside locally.

For ROSAT data it's much better to go to the horse's mouth, which provides 12.5 arcminute resolution:

`http://www.xray.mpe.mpg.de/rosat/survey/sxrb/12/ass.html`

For WMAMP, COBE, IRAS: the NASA website that provides access to NASA databases WMAP, COBE, IRAS...and a few others that are more specialized, go to

`http://lambda.gsfc.nasa.gov`

WMAP provides CBR-quality maps in 5 frequency bands extending from 23 to 94 GHz.

IRAS provides classic maps of dust IR emission 12, 25, 60, 100 microns. Angular resolution is claimed to be 0.5 arcmin at 12 microns, 2 arcmin at 100 microns, but is not this good in practice.

COBE/DIRBE: IR brightness maps in 10 bands from 1.24 to 240 microns. Of interest for diffuse interstellar radiation are maps at 12, 25, 60, 100, 140, 240 microns. Angular resolution is somewhat worse than IRAS. See DIRBE explanatory supplement for instrumental details.

IMPORTANT COMMENT

Most NASA facilities, including all the above and also HST, use IDL for data processing, analysis, and presentation. Most of the sites have IDL libraries for accessing and treating the data. It behooves you to learn and know IDL. If you are a complete novice, you can get an introduction by going to

`http://astron.berkeley.edu/~heiles/ay250/handouts.html`

and clicking on
`idltut1.ps`, `idldatatypes.ps`, `idltut_plot.ps`.

MAP PROJECTIONS

You make a map on the spherical sky and want to publish it on a flat computer screen or sheet of paper. Unless your area is small, or unless you publish on the spherical version of *Ap.J*, you can't avoid dealing with the resulting distortions.

Some important concepts:

- **Preserving shapes; this means preserving angles. Obviously a good idea if you want to represent objects to the eye faithfully. You can only do this "locally". Projections that preserve shapes are called *conformal*.**
- **A *perspective* projection is what you'd see by placing your eye at one position, at the single focal point from which a line emanates through the spheridcal surface and ends up on the projecting surface.**
- **Scale. Scale is the conversion from angle to linear distance on the map ("inches per mile") on an Earth map. The scale of the projection usually changes as you move around.**
- **Preserving pixel area, good for statistical analysis.**

Some important references:

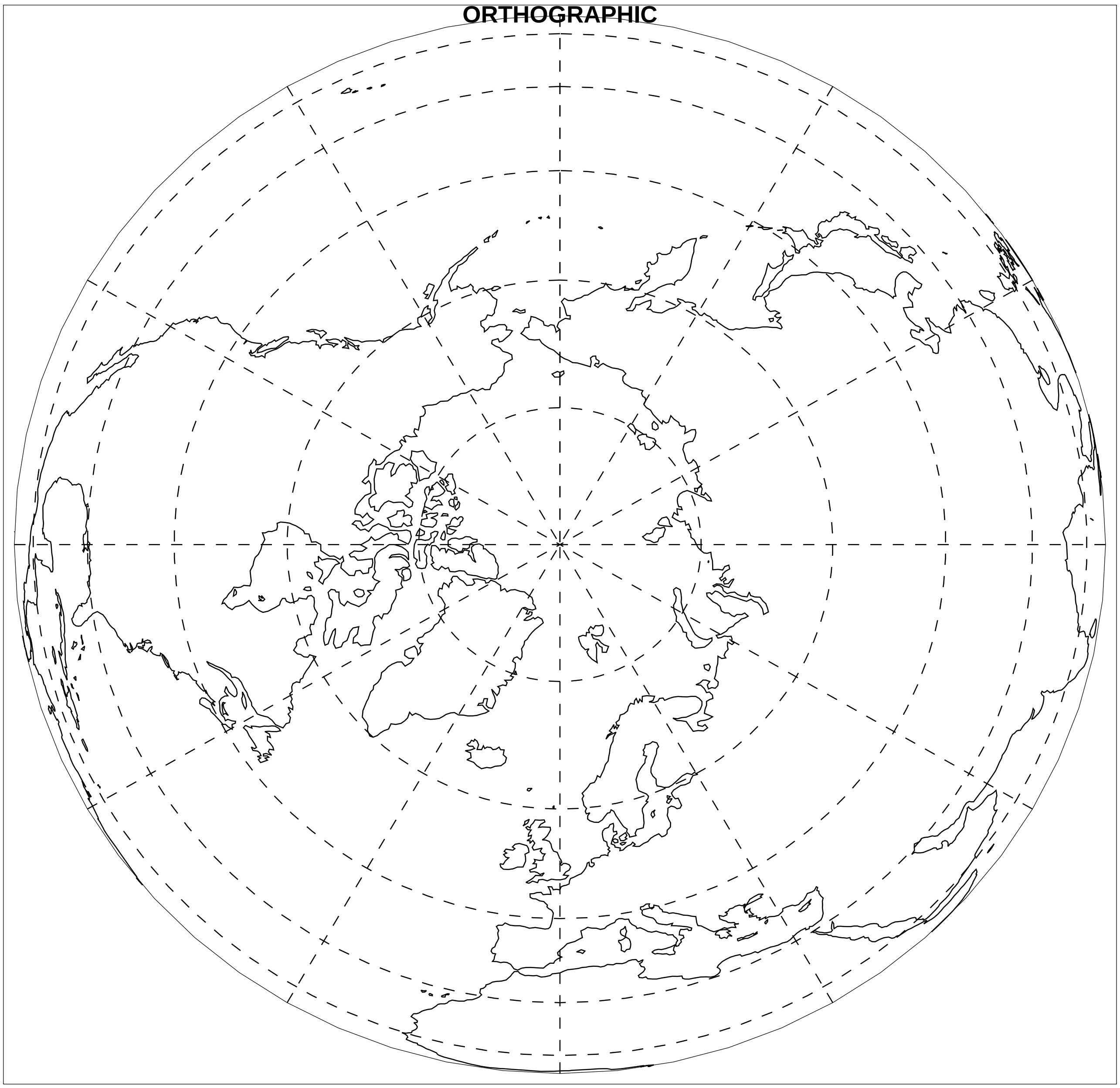
- **Basic concepts are well-explained and illustrated in IDL's documentation** *USING IDL*, **chapter 13.**
- **Clear conversion formulae are given by**
  `mathworld.wolfram.com`

  Type in the name of the projection in their search miniwindow and it gives you a nice little description.
- **For more info on any named map projection, use** *Google* **.**

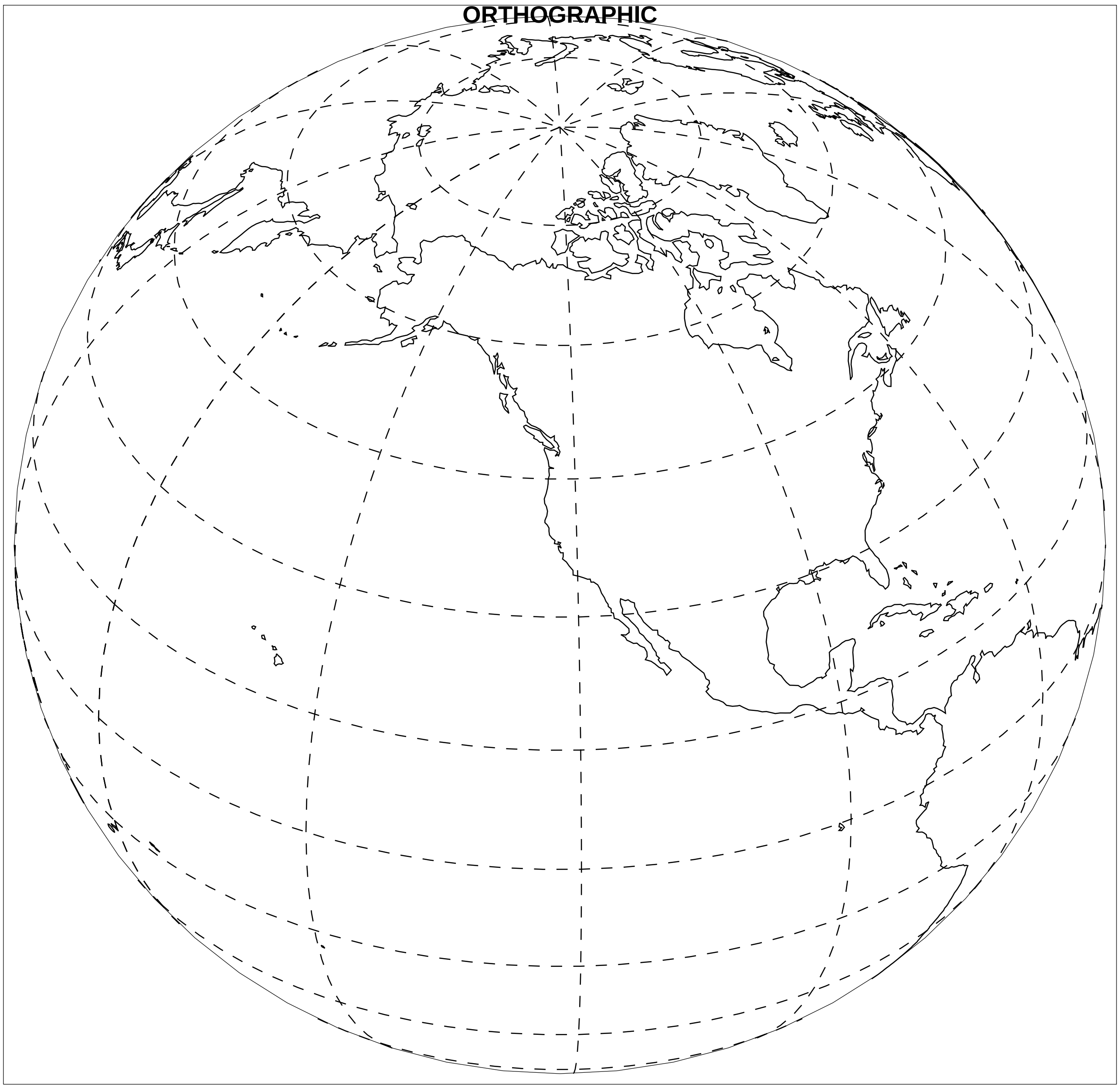
AZIMUTHAL PROJECTIONS

For an *azimuthal* **projection you place a plane tangent to the sphere. The point of intersection is center of the map. For the Earth the easiest example is the center at the North pole, but the center can be anywhere. Most are perspective projections.** *None* **have equal area pixels. In the maps below, the circles are** 15° **apart. Important azimuthal projections include:**

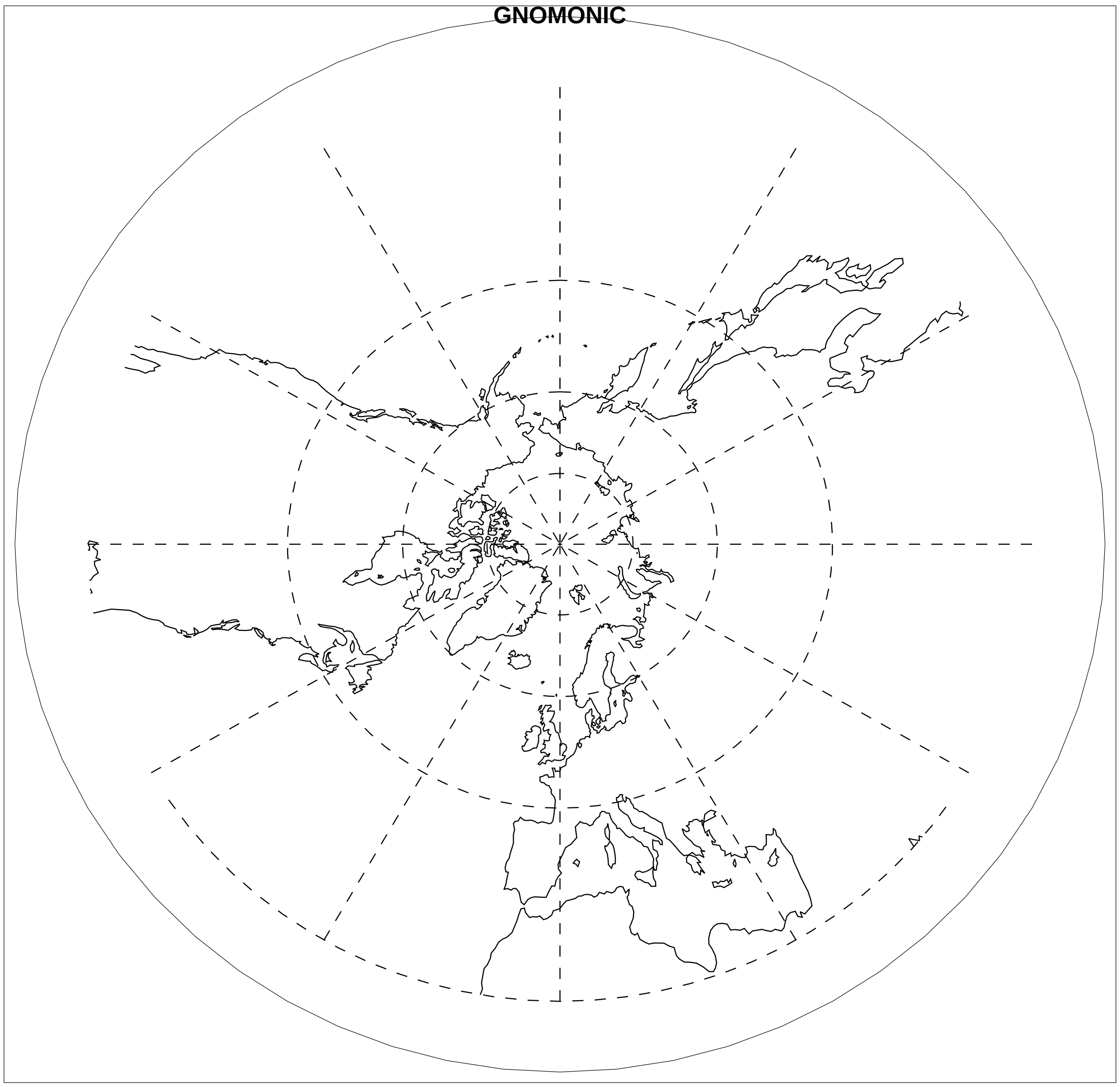
- *Orthographic*: **The focal point (the eye) is at infinity. This is not conformal: think about looking at a globe, the countries near the edge are very compressed radially.**



- *Orthographic on Berkeley*: **The focal point (the eye) is at infinity. This is not conformal: think about looking at a globe, the countries near the edge are very compressed radially.**



- *Gnomonic*: **The focal point is the center of the sphere. This not conformal: think about where the equator falls at infinity!). The advantage: straight lines in the projection are great circles on the sphre, so it's really good for airplane pilots.**



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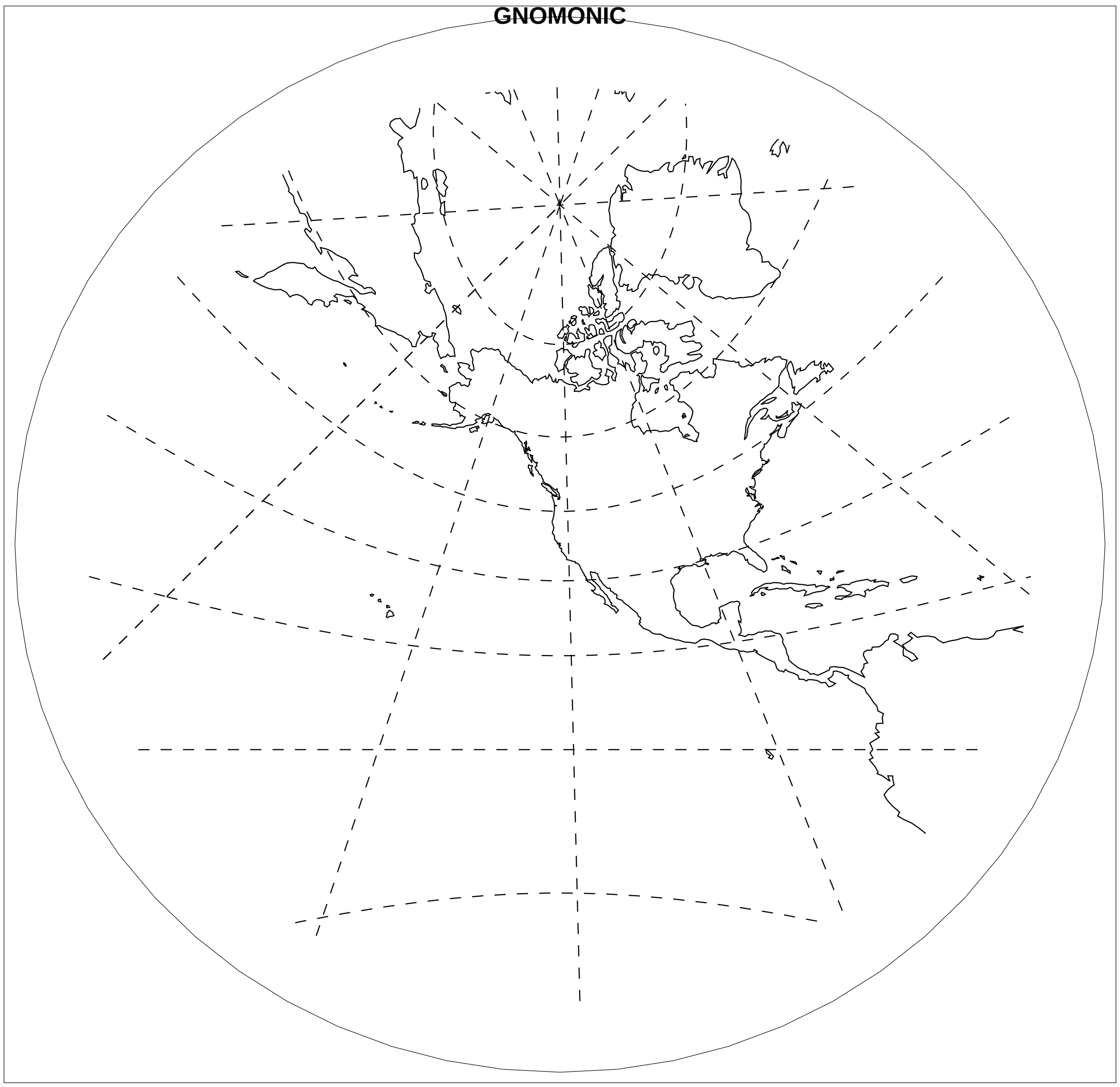
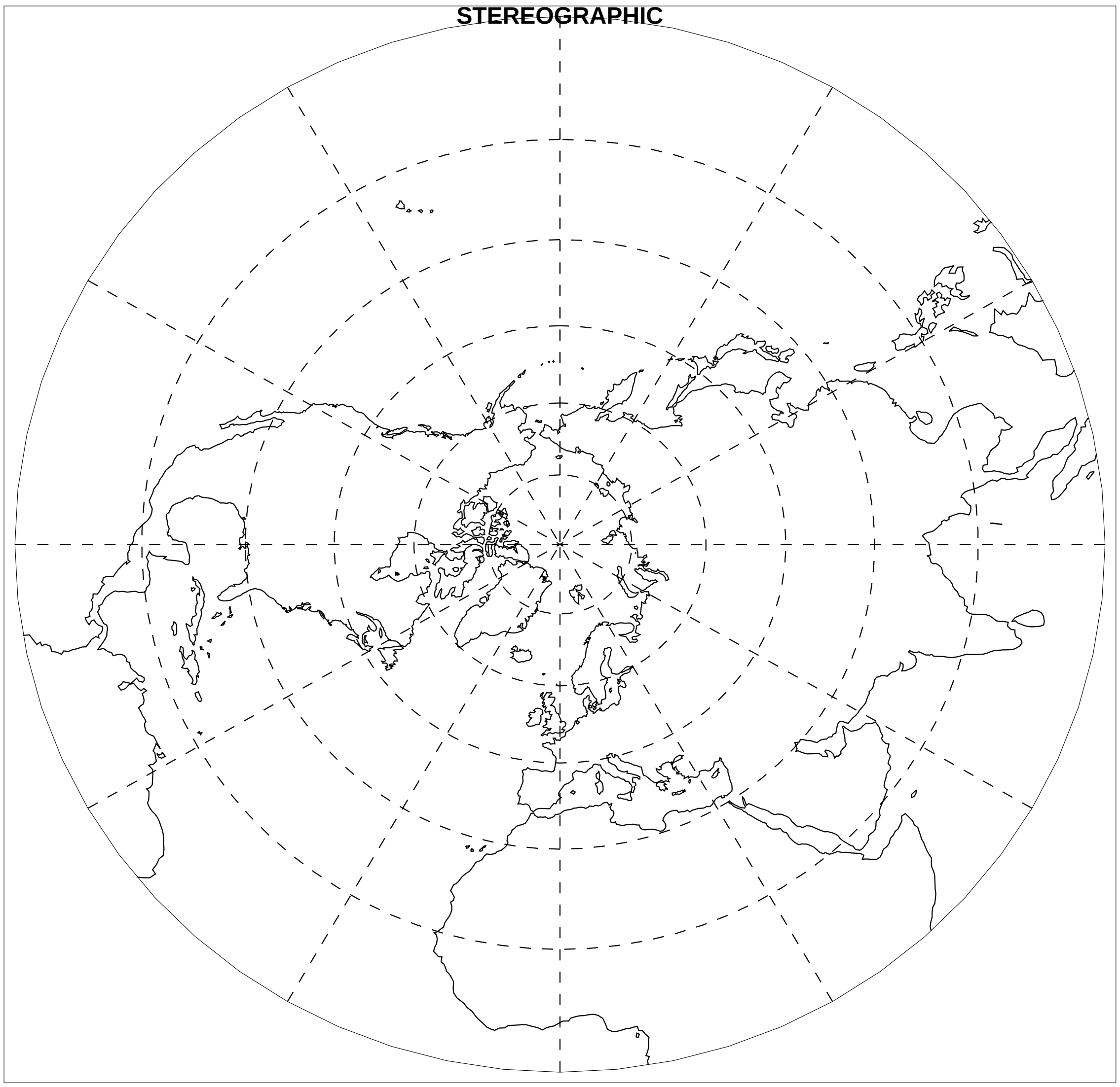


- *Stereographic*: **The focal point is at the opposite "pole" of the sphere. This** *is a conformal projection* **and is therefore highly desireable for astronomy. For a hemisphere, the scale increases by a factor of two from center to edge, which is quite good.**



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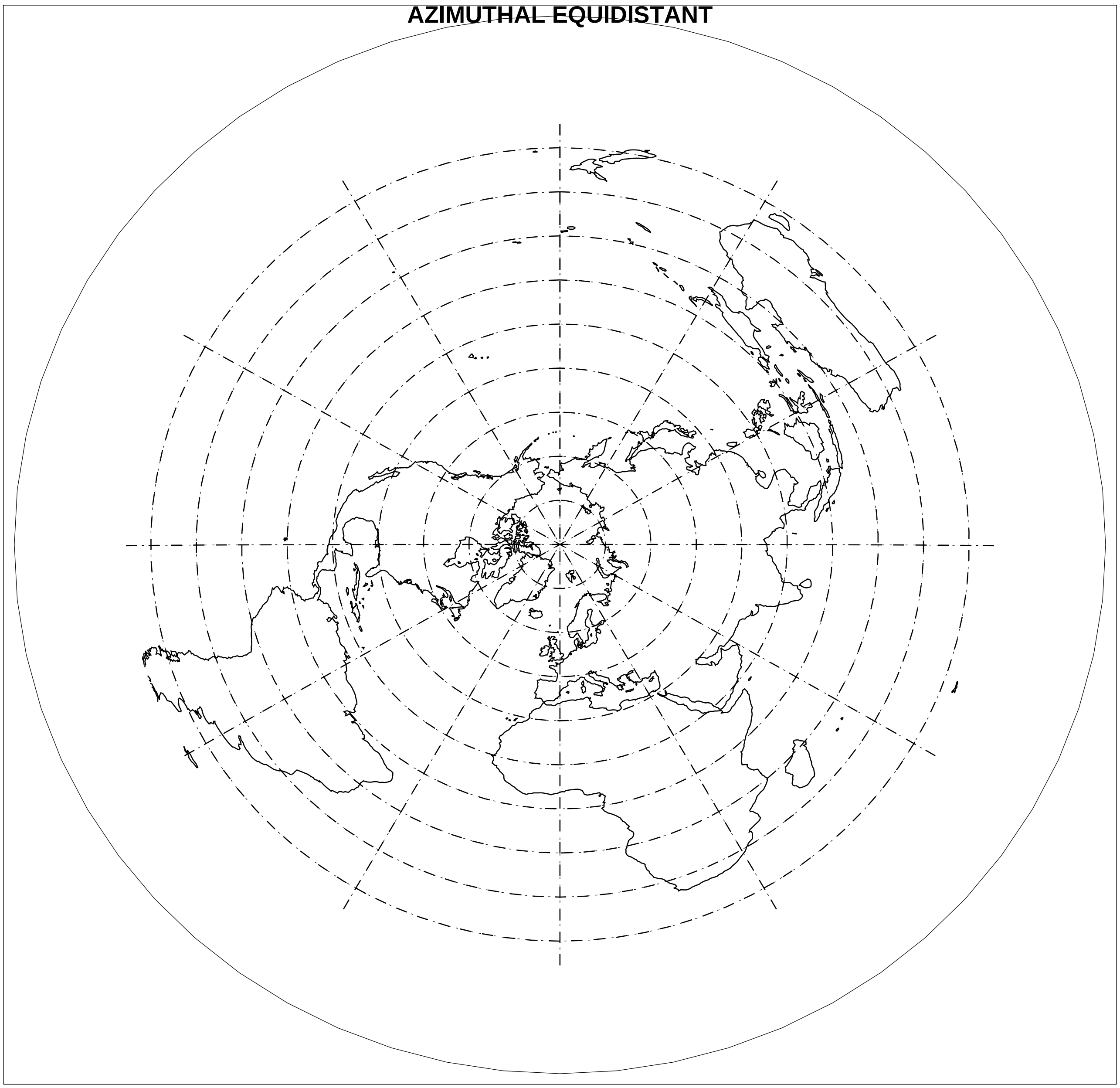
- *Azimuthal Equidistant*: **This is *not* a perspective projection. You simply make the radial scale constant everywhere. This is not conformal. Big advantage: you can easily read off the position with a ruler.**



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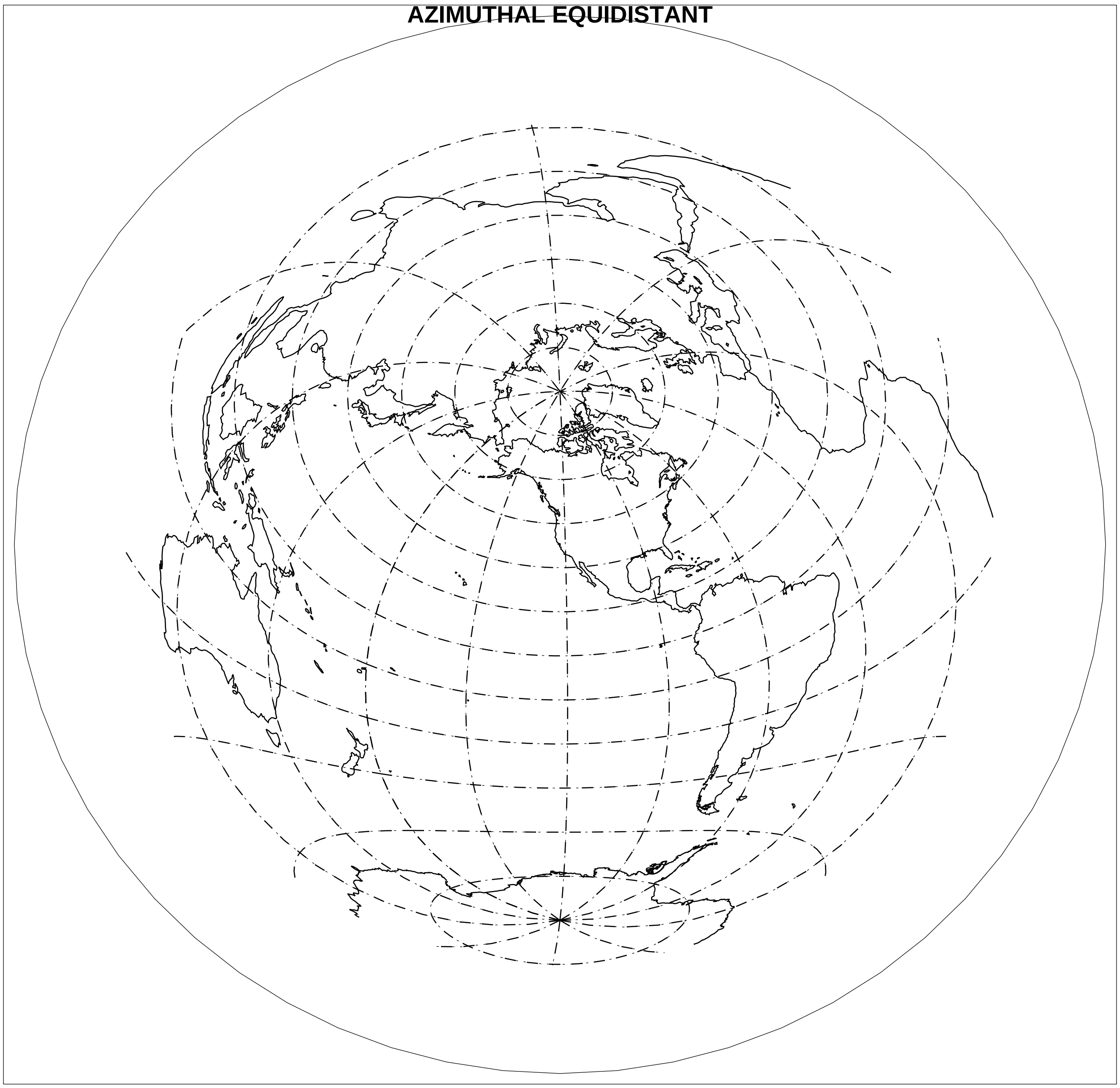
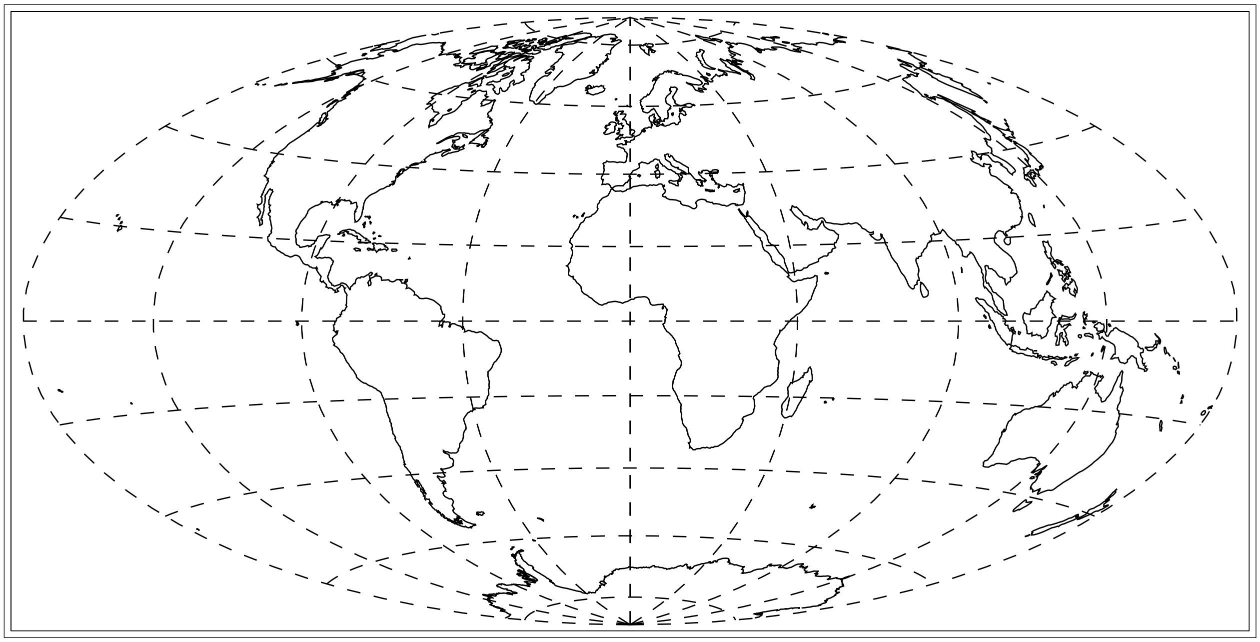


PSEUDOCYLINDRICAL PROJECTIONS

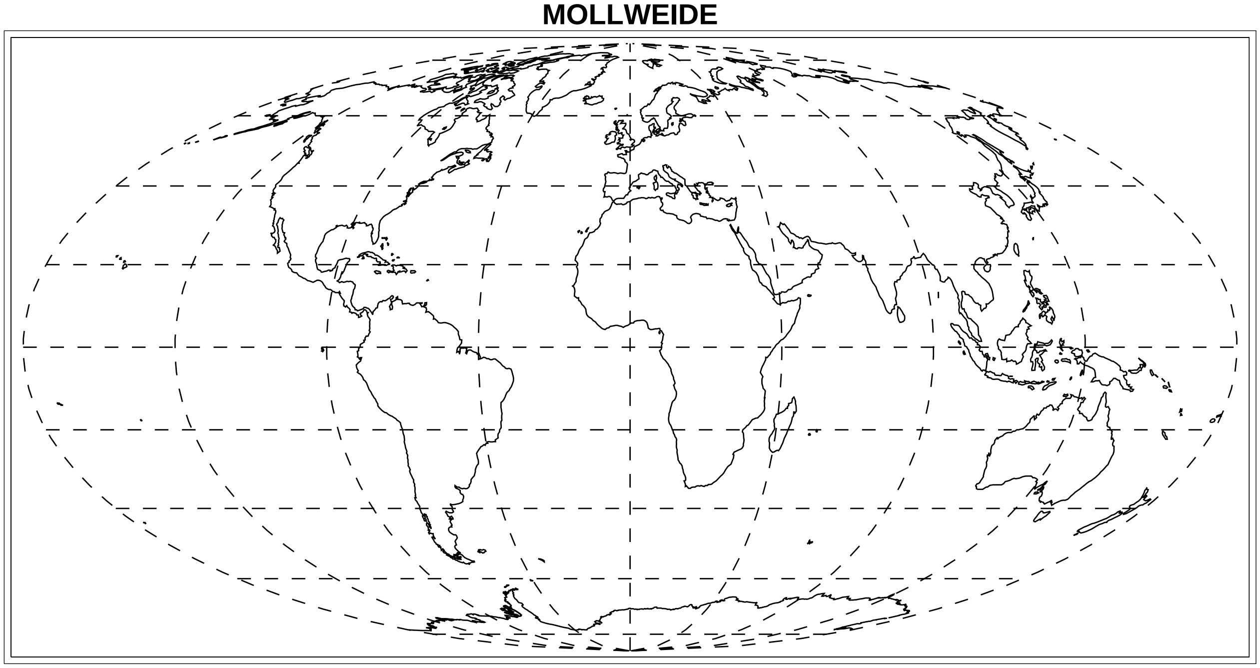
Cylindrical projections have the piece of map paper wrapped around a great circle of the sphere. The projection is made and the paper is unwrapped and published in the flat-earth *ApJ*. **These are usually chosen to have equal area pixels, which makes them attractive for the rigorously-scientifically-minded crowd who appreciates statistics more than the mental image and aesthetics. None are perspective projections. None are conformal; in fact, distortions are** *really bad*.

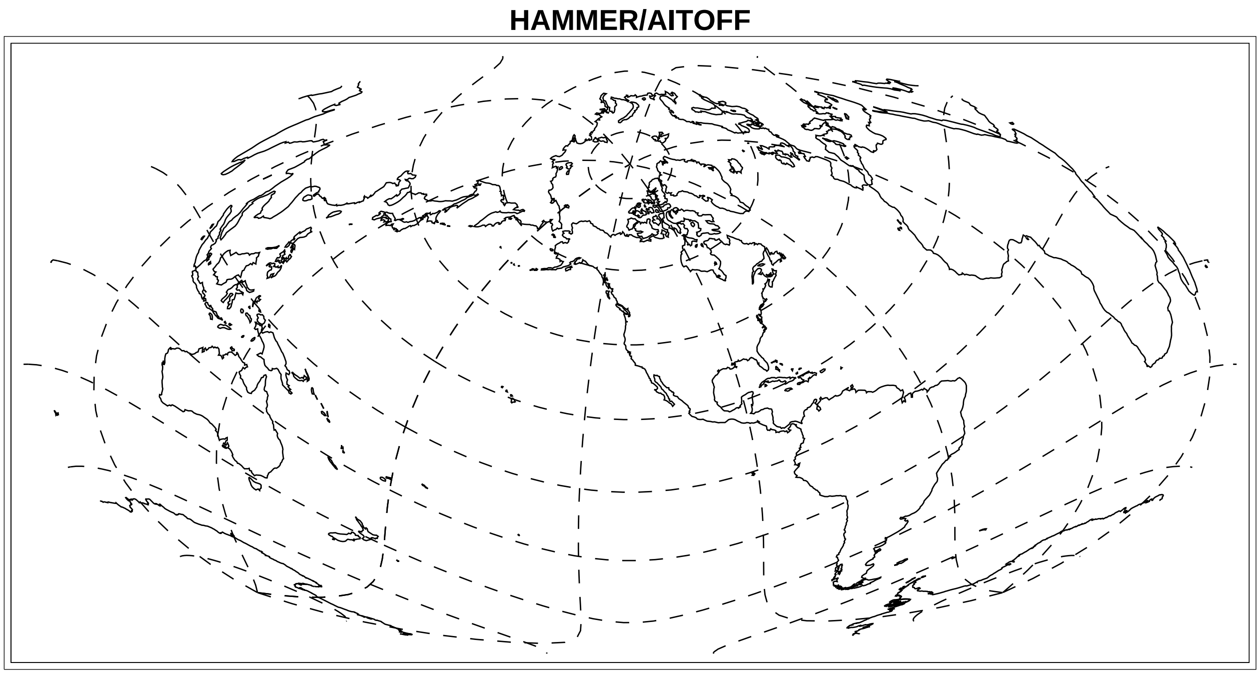
- *Aitoff*: **The entire sphere fits onto an ellipse with 2:1 axial ratio.**
- *Mollweide*: **Much like the Aitoff. The entire sphere fits onto an ellipse with 2:1 axial ratio.**

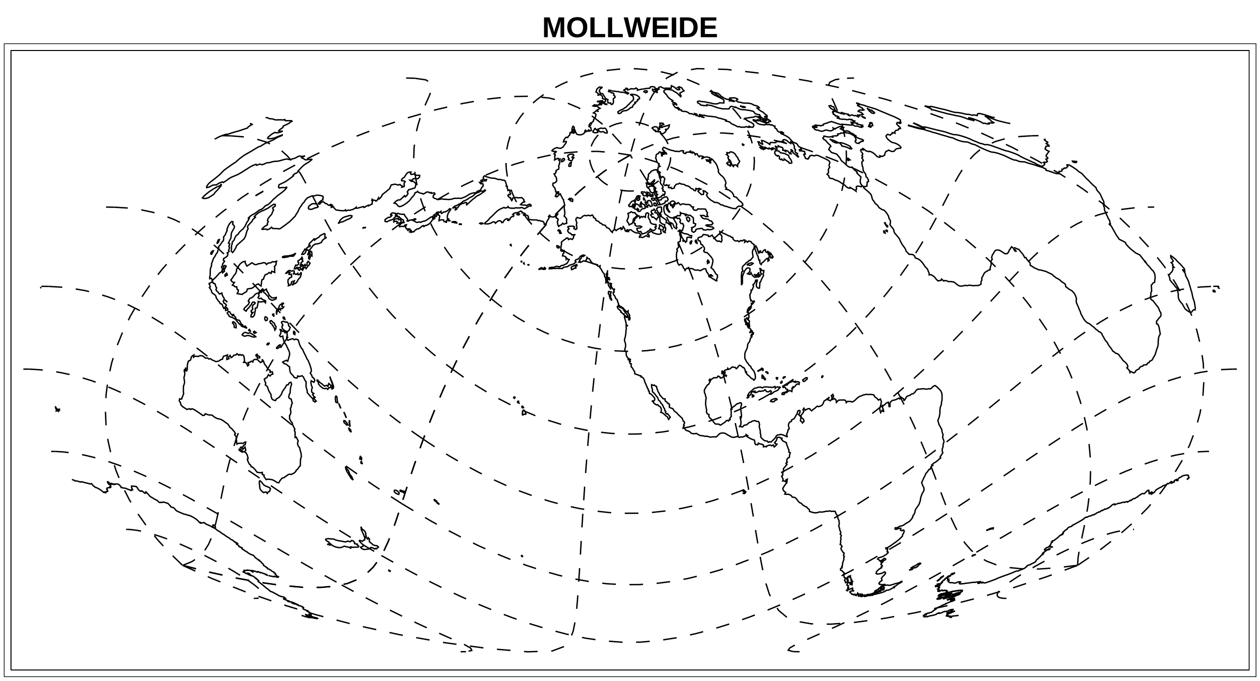
HAMMER/AITOFF



MOLLWEIDE

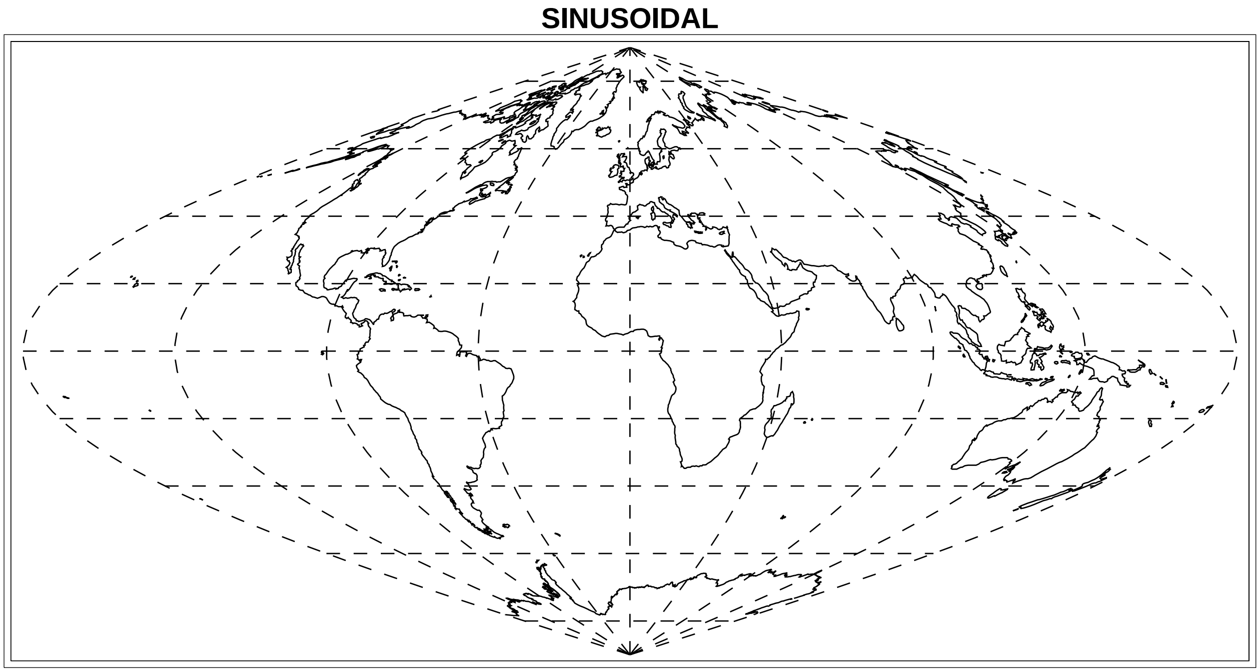


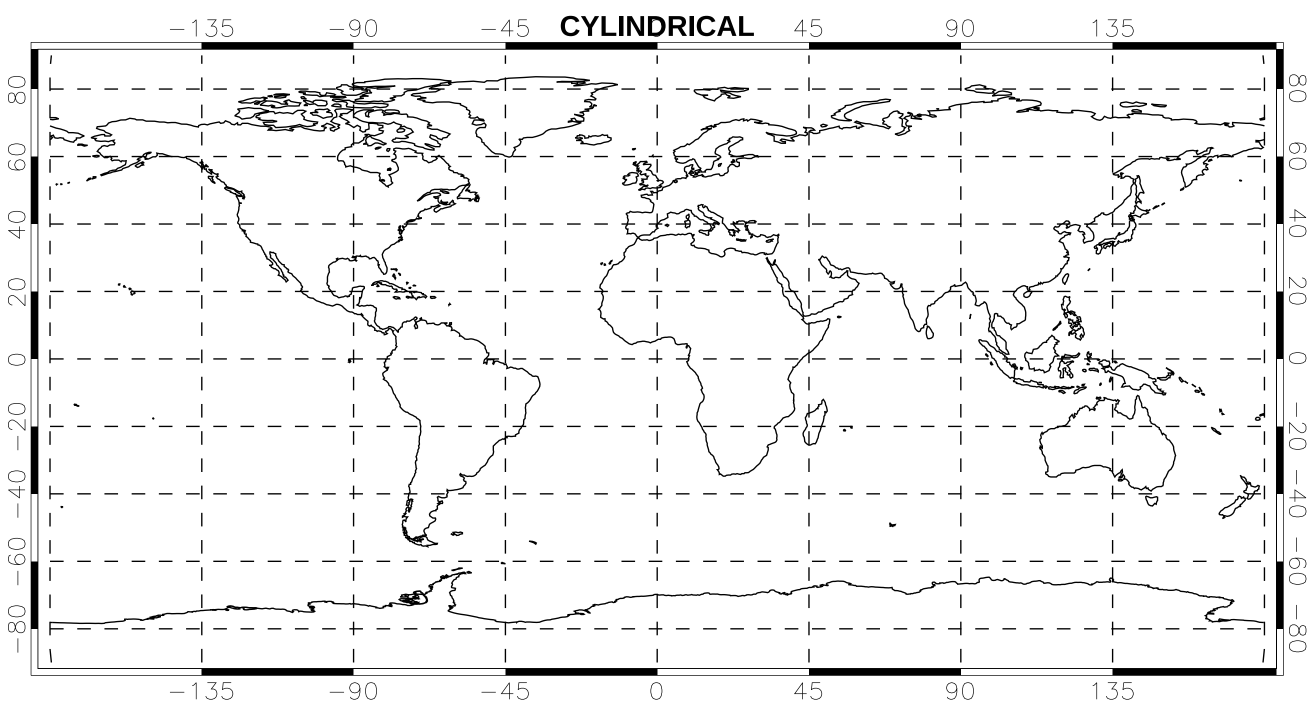

HAMMER/AITOFF


MOLLWEIDE

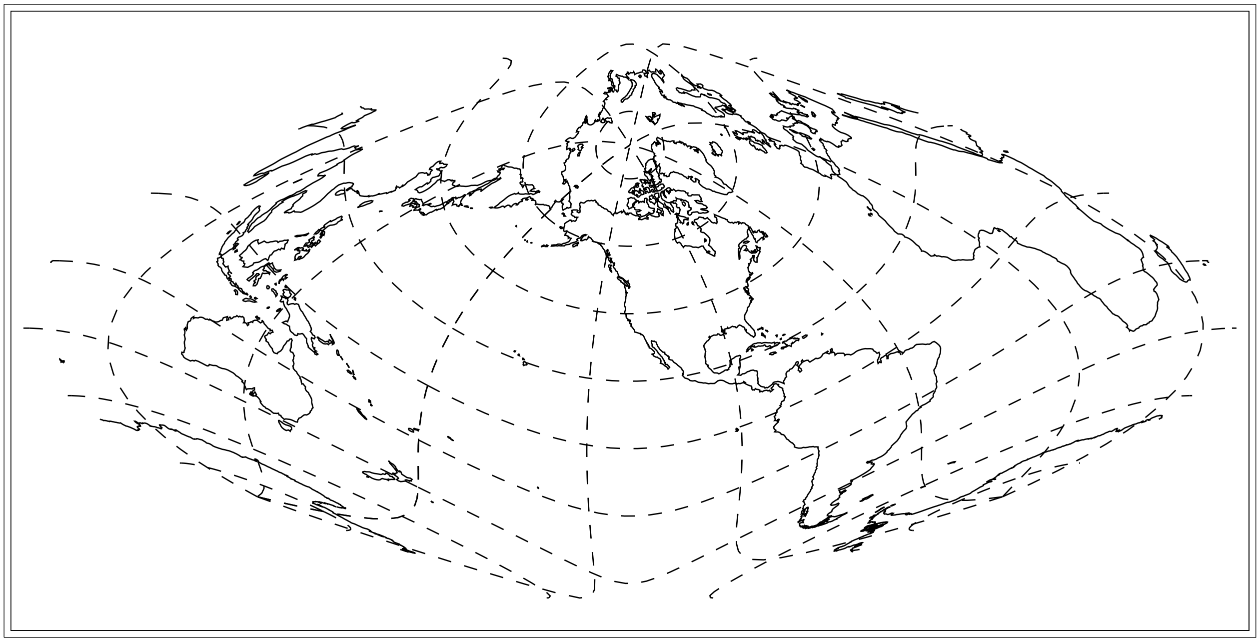
- *Sinusoidal*: **The horizontal length is the cosine of the distance from the equator, which makes the pixels equal area.**

- *Cylindrical equidistant*: **A simple cylinder with latitude scale constant. Transformations are easy and can be measured with a ruler. Useful for projections near the equator. If the latitude is stretched to make equal area pixels, then it's called "equivalent cylindrical".**

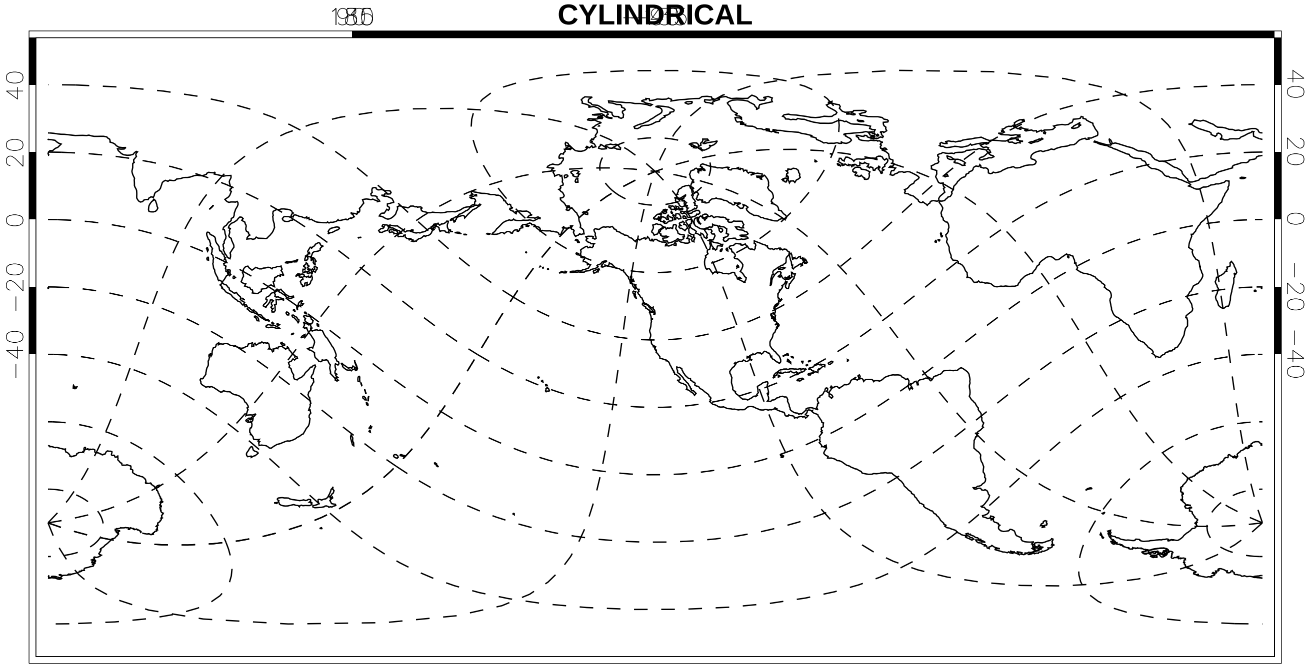

SINUSOIDAL


CYLINDRICAL
−135
−90
−45
0
45
90
135
80
60
40
20
0
−20
−40
−60
−80

SINUSOIDAL



CYLINDRICAL



HEALPIX

HEALPix (Hierarchical Equal Area isoLatitude Pixelisation of the sphere) is a spherical pixelization scheme, initially developed by Gorski, Wandelt, and Hivon, which is used by many CMB investigations, including WMAP. The sky is hierarchically tessellated into curvilinear quadrilaterals. The lowest resolution partition is comprised of 12 base pixels. Resolution of the tessellation increases by division of each pixel into four new ones. Areas of all pixels at a given resolution are identical. Pixels are distributed on lines of constant latitude, facilitating applications involving spherical harmonics. A suite of Fortran and IDL software tools for working with HEALPix format maps is available from the HEALPix web site, at
`http://www.eso.org/science/healpix/`

While you're at this website, note in particular

- **II. The Principal Characteristics of HEALPix**
- **III. What Can HEALPix Do For You?**
- **IV. New Features in the Current Release of HEALPix**
- **VI. HEALPix Documentation in Postscript Format in particlar: the HEALPix primer**

Doug Finkbeiner's useful, unbiased comments about HEALpix can be found at `http:// astron.berkeley.edu/dust/cmb/data/healpix/caveat.html`
Advantages of HEALpix include

- **All pixels have equal area.**
- **Pixel shape distortion is relatively small.**
- **Pixels are aligned on iso-latitude rings, which is necessary for fast spherical harmonic transforms!**
- **Fast and accurate routines exist for computing full sky CMB power spectra. This also applies for structural and turbulent power spectra of the interstellar gas.**
- **Pixels may be ordered in a hierarchical manner, so that pixels which are close on the sphere are also near each other in memory.**
- **Because of the great ease and speed with which spherical harmonic transforms may be computed, HEALPIX is a very convenient pixelization to use for convolving a skymap with a symmetric point-spread function (or beam).**

However, HEALpix also has some disadvantages.

- **Finding nearest neighbors is easy, but not trivial as in a 2-D image.**
- **Interpolation is non-trivial.**
- **Computing a local median filter is cumbersome and slow. Median filters are often used to detect point sources and eliminate bad pixels.**
- **The HEALPIX sphere may not be viewed in its native pixelization. It must always be reprojected, introducing repixelization effects (which are small for a well-sampled image, but important in some applications.)**

PROJECTIONS IN FITS

FITS files contain headers.

- **A well-prepared FITS file header contains all information required about the projection.**
- **The bible of FITS projection info is "Representations of Celestial Coordinates in FITS" by Eric Greisen and Mark Calabretta (2002, A+A, 395, 1061). This paper may be obtained from**

  `http://www.aoc.nrao.edu/~egreisen/`
  `http://www.atnf.csiro.au/~mcalabre/`

- **This paper is valuable reading for anyone presenting or storing data in FITS.**

FITS AND IDL

Go to Goddard IDL page, click on "One-line Descriptions of Procedures", scroll down to "FITS Astrometry and Calibration" and click "README".

Brief usage of fits:

```
img= readfits( halpha_path+ '167.sm.fits', hdr)
-- (read fits file w hdr)

extast,hdr,astr
-- EXTract ASTrometry info from projection structure
           in hdr

ad2xy, raarr, decarr, astr, x, y
--given ra, dec arrays, get the x,y pixel values

xy2ad, x, y, astr, a, d
--given x, y arrays, get the ra, dec
```